NSWCCD-50-TR-2008/093 Resistance and Component Hull Interactions of a High-Speed Trimaran Sealift Ship

Naval Surface Warfare Center
Carderock Division
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Resistance and Component Hull Interactions of a High-Speed Trimaran Sealift Ship

by

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Multi-hull vessels potentially offer several advantages over conventional monohull ship designs for a variety of operational requirements. Predicting the nature and extent of the interaction between the component hulls is a complex hydrodynamic issue. In this experiment, a resistance model test of high-speed sealift trimaran was performed, varying the position and angle of the side hulls relative to the center hull. Forces on the side hulls were measured in addition to the overall drag of the trimaran. In addition, the component hulls were tested separately in order to explore the nature and extent of interaction effects.

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US Customary and Metric Equivalents

1 foot per second (ft/s)	0.3048 meter per second (m/s)
1 knot	0.5144 meter per second (m/s)
1 pound force (lbf)	4.4480 newtons (N)
1 degree angle	0.01745 radians
1 horsepower (hp)	0.7457 kilowatts (kW)
1 long ton (LT)	1.016 metric ton, tonne (MT, t)
	1016.0 kilograms (kg)
1 inch water @60 degrees Fahrenheit	248 pascals (Pa)

Notation

The notation used in this document is compatible with the International Towing Tank Conference (ITTC) Symbols and Terminology List. http://ittc.sname.org/documents.htm

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Abstract

Multi-hull vessels potentially offer several advantages over conventional monohull ship designs for a variety of operational requirements. Predicting the nature and extent of the interaction between the component hulls is a complex hydrodynamic issue. In this experiment, a resistance model test of a high-speed sealift trimaran was performed, varying the position and angle of the side hulls relative to the center hull. Forces on the side hulls were measured in addition to the overall drag of the trimaran. In addition, the component hulls were tested separately in order to explore the nature and extent of interaction effects.

Administrative Information

This test series was sponsored by Joint High-Speed Sealift/Sealift Research & Development. The JHSS Hydro Working Group (HWG), which includes representative from NAVSEA, NSWCCD, ONR and CSC, coordinates all hydrodynamic, structural, propulsion, hull form and structural R&D for the JHSS program. Testing was conducted at the David Taylor Model Basin, Naval Surface Warfare Center, Carderock Division Headquarters by the Resistance & Propulsion Division (Code 5800) under work units 08-1-2125-146 and -147.

Introduction

Multi-hull vessels potentially offer several advantages over conventional monohull ship designs for a variety of operational requirements. These advantages can range from improved ship motions to large arrangeable areas. For high-speed ships, trimarans have shown potential for reductions in resistance by allowing the use of an extremely long and fine center hull to reduce operating Froude Number and wavemaking resistance. The outer hulls stabilize the center hull in transverse roll, and potentially further reduce wavemaking resistance by producing their own wave systems that partially cancel those of the main hull.

Predicting the nature and extent of the interaction between the component hulls is a complex hydrodynamic issue. The potential beneficial interaction effects of appropriately designed and positioned side hulls have been shown to amount a 30% reduction in effective horsepower over a baseline configuration. [1] By the same token, a badly configured trimaran can pay a steep performance penalty.

Computational methods can provide guidance on appropriate configurations, but physical model testing often reveals interaction effects that computation does not. Trimaran model testing tends to be complex and time consuming, requiring the use of multiple experimental set-ups and model configurations. The database of trimaran model experiments that methodically test a number of trimaran configurations as well as the

component hulls separately in order to isolate the drag due to interaction effects is surprisingly limited.

The goal of this test series was to perform such a methodical test for a center hull whose characteristics were well understood and to examine the cxtent and nature of interaction effects and to explore model testing and analysis techniques for use in future multihull research and acquisition programs.

In addition to the usual experimental parameters of side hull position relative to the center hull, this test series also considered a number of other variations that were considered to have potentially significant effects on interaction drag.

- Because of their proximity to the much larger center hull, the side hulls are operating in a distinctly non-uniform and asymmetric flow field. Previous experiments have shown that changing the angle of the side hulls in the x-y (water) plane of the ship can lead to reductions in drag. The previous experimental series was restricted by available time and funding, and did not find an angle that led to minimum drag. A wider range of angles was to be considered in this experiment in order to identify trends in resistance effects.

- The wave interaction of the component hulls may significantly change their wetted surface relative to the still waterline value assumed in the standard methodology for resistance and powering calculations. A wetted surface survey was performed at a ship speed of 39 knots, and calculations were performed using actual wetted surface to evaluate the effects on apparent interaction drag.

- Because the center hull of a typical trimaran design is so much larger than the side hulls, the running trim of the trimaran is dominated by that of the center hull. This forces the side hulls to operate at a trim angle that may be vcry different from their natural condition when operating alone at the same speed. Some portion of the apparent interaction effect must be due to the change in drag caused by this change in trim. The resistance of the side hulls alone was considered in both the free to sink and trim (natural) condition and fixed in sinkage and trim as though they were operating in the presence of the center hull.

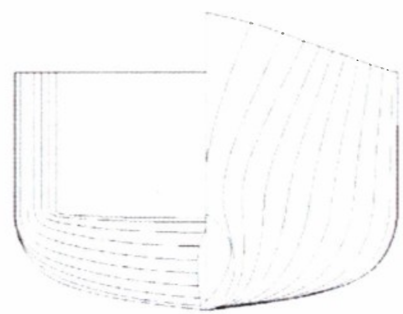
Model and Rigging Information

The center hull model selected for the test was DTMB model number 5688, the Joint High-Speed Sealift monohull at a scale ratio of λ=47.53. This model represents the four-screw JHSS propulsion configuration with the gooseneck bulb, and was originally constructed for seakeeping tests. It is a geosim of model number 5653, the λ=34.121 resistance model. While it was designed to operate as a monohull, it is nonetheless quite slender and potentially suitable for operation in a trimaran configuration. Undcr the JHSS

research and development program, this hull design has been tested in a wide variety of conditions and propulsion configurations, and as a result its performance and characteristics as a monohull are extremely well understood.

The side hulls were slender, round-bilge hulls designed at NSWCCD using the guidelines given in [2]. The characteristics of the side and center hulls are given in Figures 1 and 2. The submerged portion of the side hulls are symmetric about their center lines, and have relatively deep transoms (A_T/A_X=0.451, B_T/B_X=0.563), which may further emphasize the trim effects discussed above.

Name:	Center Hull, 90% of total Trimaran Δ, 10% total Δ in Side Hulls
Rhino File:	C:\Documents and Settings\SlutskyJG.NSWCCD\My Documents\Test Files\JHSS Trimaran\5688 Trimaran Full Scale Hydrostatics Model.3dm



PRINCIPAL DIMENSIONS

Length (LOA)	982.1 ft	299.3 m
Length (LWL)	976.4 ft	297.6 m
Beam (B_X)	104.9 ft	32.0 m
Mean Draft (T_x)	28.8 ft	8.8 m
Max Draft (T_{Max})	28.8 ft	8.8 m
Trim (Deg +bow up)	0.0 ft	0.0 m
Displacement (SW)	80918164.8 lb	36704238.8 kg
	36124.2 LT	36704.2 MT
Wetted Surface		
Bare Hull	105966.8 ft^2	9844.9 m^2
Appendage	4689.9 ft^2	435.7 m^2
(Total)	110656.7 ft^2	10280.6 m^2

NONDIMENSIONAL COEFFICIENTS

C_B	0.428	C_{VP}	0.605	FB/LWL	0.516
C_P	0.532	C_S	0.000	FF/LWL	0.603
C_{PF}	0.528	LWL/B_X	9.312	100/C_V	0.136
C_{PA}	0.549	B_X/T_X	3.636	$\Delta/(.01LWL)^3$	38.805
C_X	0.804	A_T	75.460	A_T/A_X	0.031
C_{WP}	0.707	T_T	1.220	T_T/T_X	0.042
		B_T	79.240	B_T/B_X	0.756

MODEL SCALE DATA

Scale Factor	47.53	
Length (LOA)	20.66 ft	6.44 m
Length (LWL)	20.54 ft	6.26 m
Beam (B_X)	2.21 ft	0.67 m
Draft (T_X)	0.61 ft	0.18 m
Displacement (FW)	733.84 lb	332.81 kg
Wetted Surface	48.98 ft^2	4.55 m^2

Figure 1 – Model 5688 center hull characteristics

Name:	Side Hull, 5% total Trimaran Δ per Side Hull, 10% Total Δ in Side Hulls
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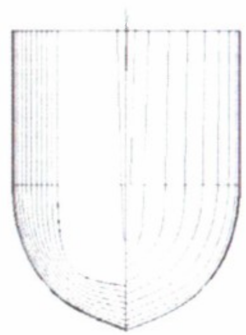

PRINCIPAL DIMENSIONS

Length (LOA)	448.3 ft	136.6 m
Length (LWL)	441.6 ft	134.6 m
Beam (B_X)	23.7 ft	7.2 m
Mean Draft (T_x)	14.1 ft	4.3 m
Max Draft (T_{Max})	14.1 ft	4.3 m
Trim (Deg +bow up)	0.0 ft	0.0 m
Displacement (SW)	4491731.1 lb	2037435.8 kg
	2005.2 LT	2037.4 MT
Wetted Surface (Total)	13833.1 ft^2	1285.2 m^2

NONDIMENSIONAL COEFFICIENTS

C_B	0.474	C_{VP}	0.624	FB/LWL	0.550
C_P	0.659	C_S	2.486	FF/LWL	0.538
C_{PF}	0.569	LWL/B_X	18.597	$100/C_V$	0.081
C_{PA}	0.740	B_X/T_X	1.683	$\Delta/(.01LWL)^3$	23.286
C_X	0.719	A_T	108.560	A_T/A_X	0.451
C_{WP}	0.759	T_T	8.910	T_T/T_X	0.631
		B_T	13.360	B_T/B_X	0.563

MODEL SCALE DATA

Scale Factor	47.53	
Length (LOA)	9.43 ft	2.94 m
Length (LWL)	9.29 ft	2.83 m
Beam (B_X)	0.50 ft	0.15 m
Draft (T_X)	0.30 ft	0.09 m
Displacement (FW)	40.74 lb	18.47 kg
Wetted Surface	6.12 ft^2	0.57 m^2

Figure 2 – Model 5688 side hull characteristics

The center hull was constructed from fiberglass with a mahogany coaming and cross braces and a marine fiberglass towing and instrumentation platform amidships. The side hulls were CNC cut from polyurethane foam and finished with an epoxy surface coating. The side hulls were originally designed for use in a structural test with a segmented center hull model, and for that purpose included crossdeck structure to measure slamming loads between the center and side hulls. For this test, in order to clearly observe the free surface between the side hulls, the port and starboard side hulls were exchanged such that the cross structure protruded outboard rather than inboard. The side hulls below the waterline were symmetrical, so this alteration did not effect the submerged geometry of the hulls or the calm water flow about them.

The overall displacement of the trimaran was set at 40135 Long Tons, which is equivalent to the heavy condition tested during several monohull test series. Assigning 5% of this displacement to each side hull gives a center hull displacement of 36124 Long tons, equivalent to the design displacement of the monohull. This allowed for a direct comparison between trimaran powering performance and that of the center hull operating in a monohull mode at equivalent total displacement.

The model was tested in a fully appended configuration including bilge keels, stern flap, rudders and shoes, and four screw shafting with dummy hubs but not fairwaters. The calculated appendage surface area including all listed appendages except for the stern flap, shafts, and struts was 435.7 m^2 (4689.9 ft^2). Appendage positions are shown in Figure 3.

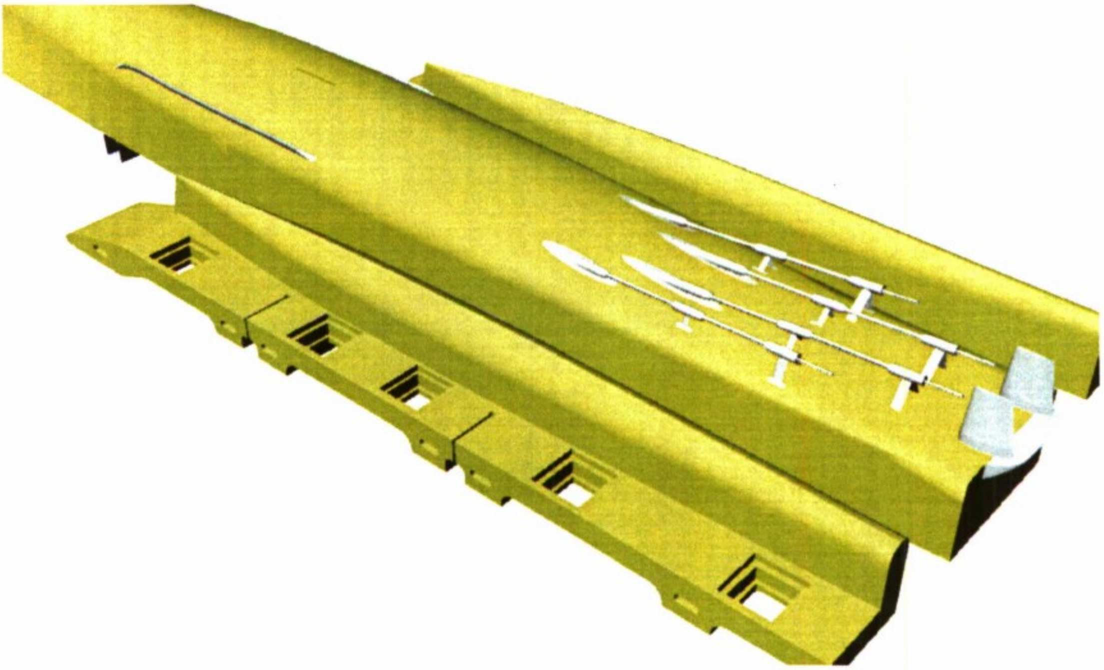

Figure 3 – Center hull stern showing appendage configuration. Centerline skeg is omitted for clarity

The NSWCCD Model Shop marked the hulls with a 2 inch grid extending +/- 4 inches about the still waterline.

For the trimaran configurations, the model was instrumented with a pair of 4 inch block gauges to measure drag and side force and string potentiometers at stations 5 and 15 to measure sinkage and trim. The starboard side hull was connected to the cross structure by a pair of AMTI 6 component gauges in order to measure drag and side force on the side hull separately from the main hull drag. An overview of the trimaran towing arrangements and instrumentation are shown in Figure 4. The model was towed from a 200 lb capacity floating towpost with a grasshopper fitted aft to control yaw. [3]

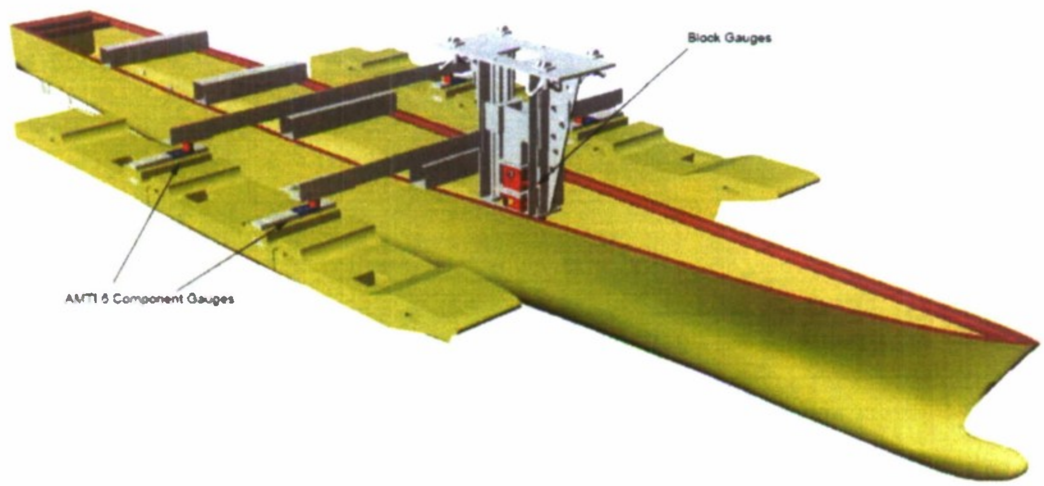

Figure 4 – Overall trimaran towing arrangements

The cross structure was constructed from aluminum beams machined such that the side hulls could slide laterally in order to change the transverse position and be pinned into place at specified positions. In order to alter the side hull angle of attack, each side hull could pivot about the position of the after AMTI gauge. Cross structure and pivot arrangements are shown in Figure 5.

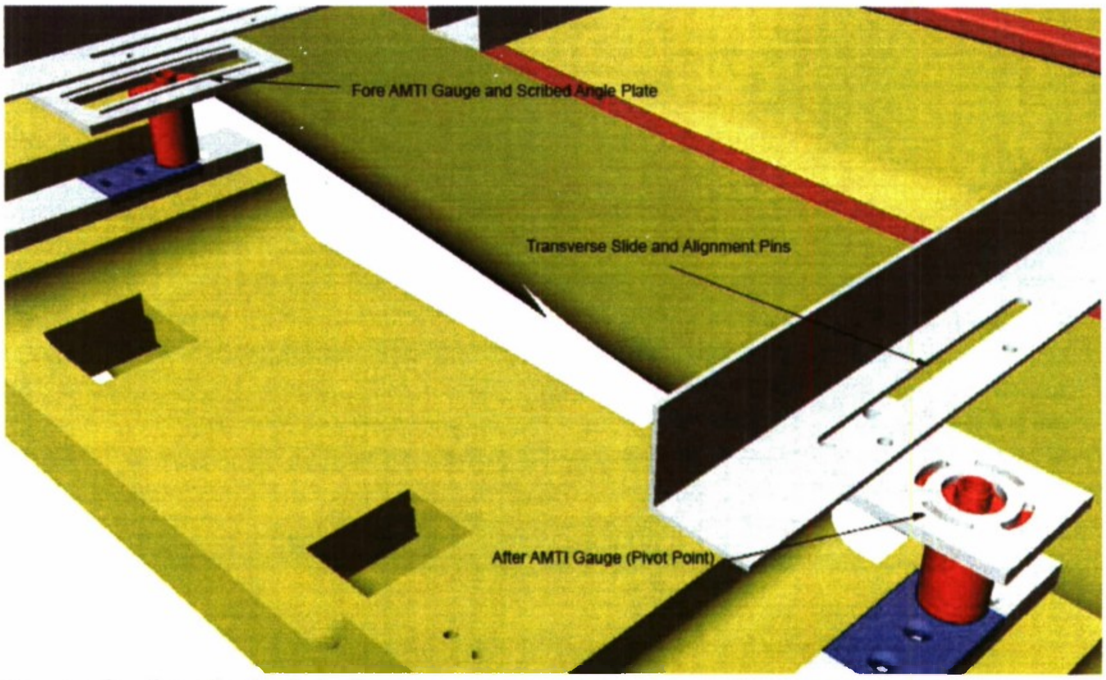

Figure 5 – Detail of side hull cross structure and pivot arrangements. AMTI gauges mounted on starboard side hull only.

Two longitudinal and two lateral positions were tested for a total of four trimaran configurations. Longitudinally, the forward position was selected such that the midships positions of the side and center hulls were aligned, and the after position such that the transoms were aligned. The transverse positions selected were full scale centerline separation distances of 96 and 120 ft (29.3 and 36.5 m), equivalent to 0.916 and 1.145 center hull beams. These positions were selected to bracket the range of commonly considered side hull positions for frigate-sized and larger trimarans. The configurations (shown as a 2-dimensional waterplane projection) are shown in Figure 6 and Table 1.

Figure 6 – Trimaran configurations

Table 1 – Stagger and Spacing values for trimaran configurations

Condition Name	Stagger (ft)	Stagger (% LWL_{Cen})	Spacing (ft)	Spacing (% B_{Cen})
Forward Inboard	254.7	26.1%	96.1	91.6%
Forward Outboard	254.7	26.1%	120.1	114.5%
Aft Inboard	0	0%	96.1	91.6%
Aft Outboard	0	0%	120.1	114.5%

In order to study the effects of the side hulls' angle of attack, 6 variations in angle were considered: +/- 1.0, 2.5, and 5.0 degrees. The angle study was based on the outboard aft side hull position and the center of rotation was about the after 6 component gauge. The angled positions of the side hulls are shown in Figure 7.

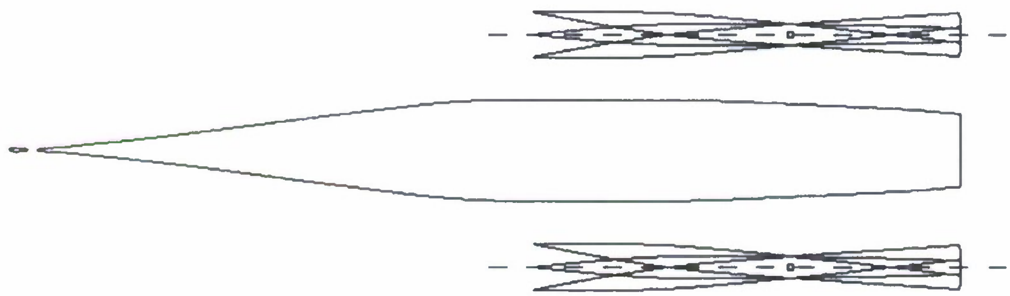

Figure 7 – Variation in Side Hull angle of +/- 5 Degrees about baseline outboard aft. +/- 1 Deg and 2.5 Deg were also tested, but are omitted from this graphic for clarity.

To test the center hull alone, the cross structure was removed and the center hull ballasted to compensate for the weight removed. The towing arrangements otherwise remained the same.

In order to test the side hulls in a catamaran configuration, the existing crossbeams were retained in order to maintain the same spacings used in the trimaran condition, and an aluminum beam was fitted to provide a centerline towing point, as shown in Figure 8. The longitudinal position of the tow point was configure such that it matched the tow point used in the trimaran configuration with the side hulls in their after position. (That is, the towpost was positioned as if it were in the absent center hull.) This position is approximately 15 inches forward of the side hulls' longitudinal center of flotation.

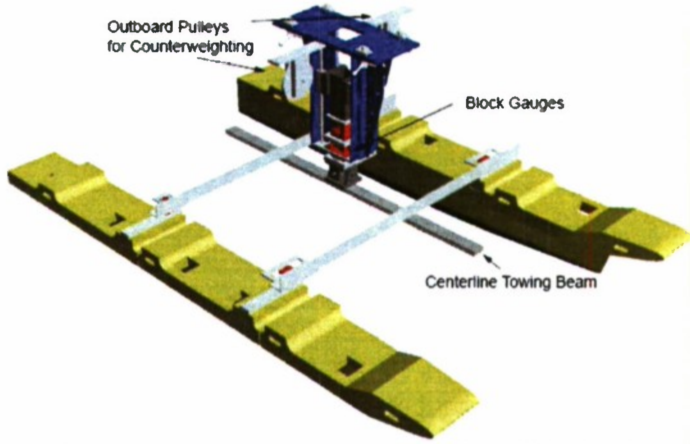

Figure 8 – Towing and instrumentation arrangements for side hulls free to sink and trim

In addition to the transverse spacings equivalent to the trimaran condition, a narrow spacing of 85.16 ft (S/LWL_{Side}=0.19) was tested in order to simulate a notional fast catamaran and to provide an additional data point on side hull-side hull interaction drag. The full range of spacings is shown in Figure 9.

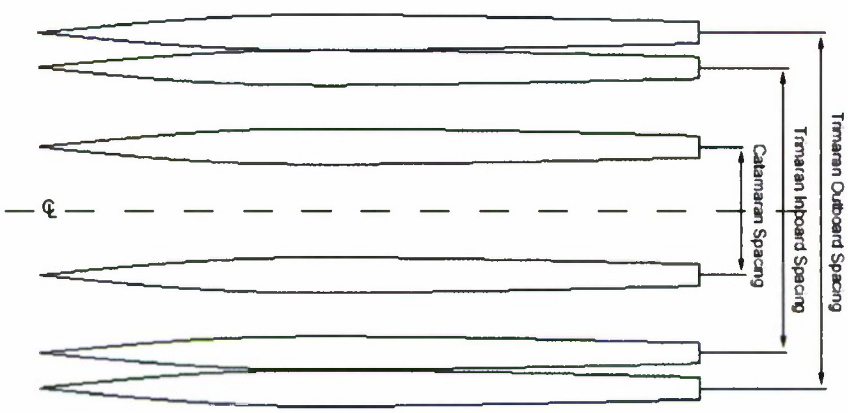

Figure 9 – Side hull spacings tested

The side hulls required extensive counterweighting, as the weight of the models, cross structure, and towing gear exceeded the displacement. Cables were attached to the floating portion of the block stack and led upwards through a pair of sheaves attached to the top of the towpost, then led outboard through another pulley to a pair of weight pans as shown in Figure 10. This method allows for counterweighting at the tow point to minimize effects on the model, but unavoidably tends to damp out the heave response of the model. A separate model of the side hulls constructed to a scale ratio that provided

adequate buoyancy to support the towing gear would be preferable, but was (and generally is) impractical for financial and programmatic reasons.

Figure 10 – Detail of counterweighting arrangements

Finally, in order to test the side hulls in a fixed sinkage and trim condition, the floating towpost was replaced with a pair of fixed platform towposts. This allowed sinkage and trim to be set manually and locked in during a run. The centerline beam had to be lowered slightly to accommodate the reduced vertical travel of the fixed platform towposts, but, as shown in Figure 11, the primary difference from the free to sink and trim side hull towing arrangement is the addition of the second towpost.

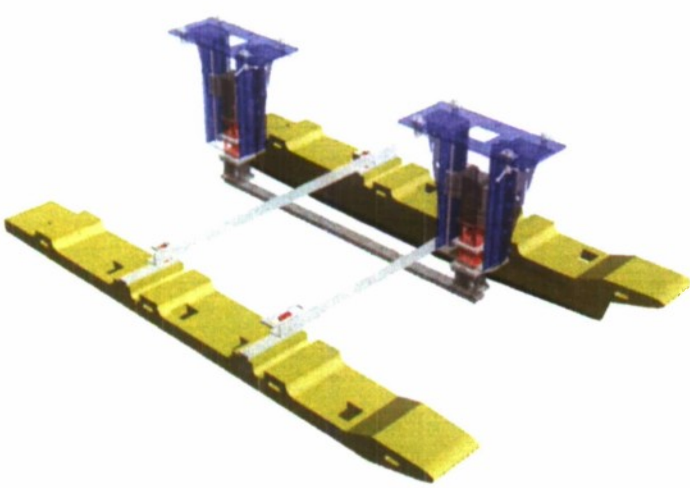

Figure 11 – Towing and instrumentation arrangements for side hulls fixed in sinkage and trim

Test Information

The test series was performed in the deep water towing basin of the David Taylor Model Basin. For all tests, unless otherwise noted, the model was towed at speeds corresponding to ship speeds from 16-45 knots. A summary of conditions tested shown in Table 2.

Table 2 – Test conditions

Test Number	Condition	Notes
1	Trimaran, Forward Longitudinal, Inboard Lateral	6-DOF Side Hull Forces Collected
2	Trimaran, Forward Longitudinal, Outboard Lateral	6-DOF Side Hull Forces Collected
3	Trimaran, Aft Longitudinal, Outboard Lateral	6-DOF Side Hull Forces Collected
4	Trimaran, Aft Longitudinal, Inboard Lateral	6-DOF Side Hull Forces Collected
5	Trimaran, Aft Longitudinal, Outboard Lateral, 1 Deg Nose Outboard	6-DOF Side Hull Forces Collected
6	Trimaran, Aft Longitudinal, Outboard Lateral, 2.5 Deg Nose Outboard	6-DOF Side Hull Forces Collected
7	Trimaran, Aft Longitudinal, Outboard Lateral, 5 Deg Nose Outboard	6-DOF Side Hull Forces Collected
8	Trimaran, Aft Longitudinal, Outboard Lateral, 5 Deg Nose Inboard	6-DOF Side Hull Forces Collected
9	Trimaran, Aft Longitudinal, Outboard Lateral, 2.5 Deg Nose Inboard	6-DOF Side Hull Forces Collected
10	Trimaran, Aft Longitudinal, Outboard Lateral, 1 Deg Nose Inboard	6-DOF Side Hull Forces Collected
11	Trimaran, Aft Longitudinal, Outboard Lateral, 1 Deg Nose Outboard Repeat	6-DOF Side Hull Forces Collected
12	Test Aborted	Test Aborted
13	Center Hull Only, Free to Sink & Trim	
14	Test Aborted	Test Aborted
15	Side Hulls Only, Inboard Lateral, Free to Sink & Trim	
16	Side Hulls Only, Inboard Lateral, Free to Sink & Trim	Continuation of Test 15
17	Side Hulls Only, Outboard Lateral, Free to Sink & Trim	
18	Side Hulls Only, Narrow Lateral, Free to Sink & Trim	
19	Side Hulls Only, Narrow Lateral, Free to Sink & Trim	
20	Side Hulls Only, Outboard Lateral, Fixed Sinkage & Trim	Fixed in Sinkage & Trim Fixed per Catamaran Condition (Test 17)
21	Side Hulls Only, Outboard Lateral, Fixed Sinkage & Trim	Fixed in Sinkage & Trim per Trimaran Inboard Forward Condition (Test 1)

Results

Unless otherwise noted, raw data was expanded to full scale values using standard NSWCCD extrapolation procedures with an assumed correlation allowance (C_A) of 0.000.

Side Hull Position Studies

The trimaran was tested with four side hull positions as stated above. The results followed the expected trend with respect to longitudinal position: effective horsepower at the after side hull positions was significantly less than that of the forward positions as shown in Figure 12.

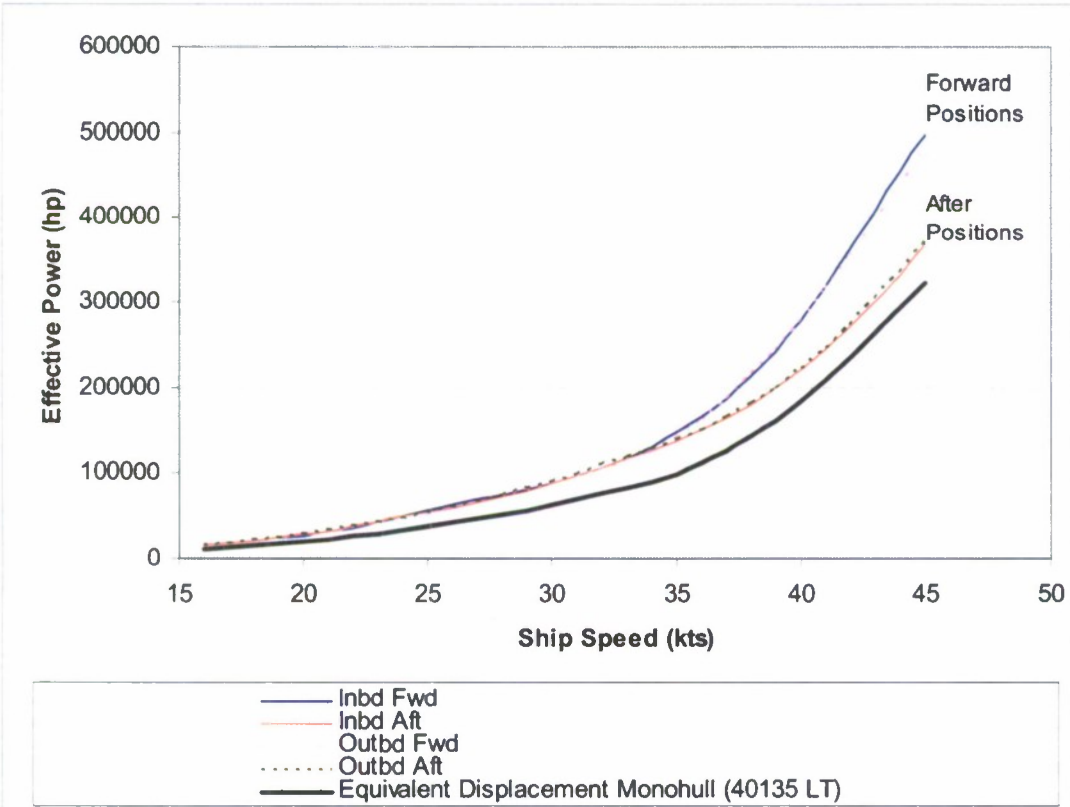

Figure 12 – Ship scale effective horsepower for varying positions of the side hulls with respect to the center hull

At the forward positions, an obviously unfavorable wave interaction was visible at the free surface between the hulls. The primary troughs of the center and side hull wave systems reinforced each other, leading to a deep trough that unwetted the center hull to the level of the bilge keels. A large crest was generated immediately aft of this hollow. For the forward inboard side hull position this crest was particularly dramatic: at 39 knots

the observed full scale crest-to-trough height of over 28 feet, and quite steep as shown in Figure 13.

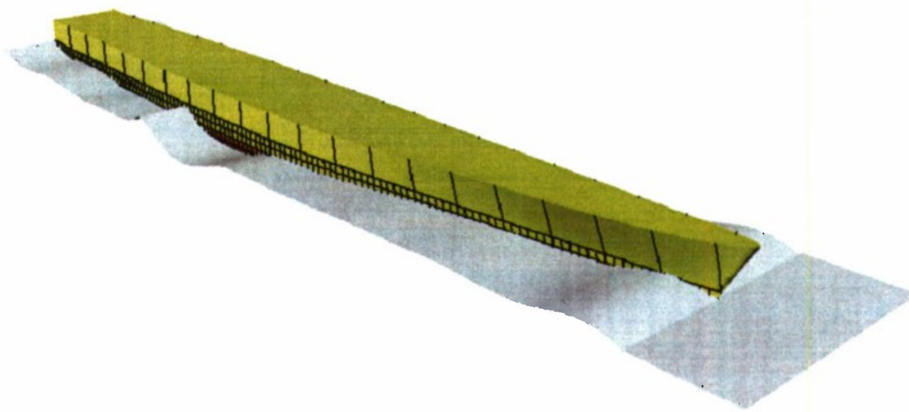

Figure 13 – Inboard center hull wave trace for the forward inboard side hull position at 39 knots

Waves between the component hulls were not observed to break for any of the conditions tested. Flow off the side hull transoms was asymmetrical for the lower 2/3 of the speed range, with the outboard free surface higher than the inboard. The side hull transoms were deeper than the current design process generally suggest as optimal unless it is intended to install waterjets in the side hulls.

It can be seen from Figure 12 that in all cases, the trimaran configuration paid a substantial EHP penalty relative to the center hull run at a monohull displacement equivalent to that of the total trimaran. Expressed as a fraction of equivalent center hull EHP for speeds greater than 40 knots, it amounts to approximately 55% additional EHP for the forward positions and 20% EHP at the after positions as shown in Figure 14. This is not unexpected – while the center hull is extremely slender, it was nonetheless originally designed as a monohull. This implies greater transverse waterplane area for stability than is necessary for a trimaran, which in turns leads to a fuller hull and greater wavemaking resistance, eliminating much of the advantage of adopting a trimaran configuration. Also see comments and Figure 17 below for further discussion of trimaran resistance characteristics.

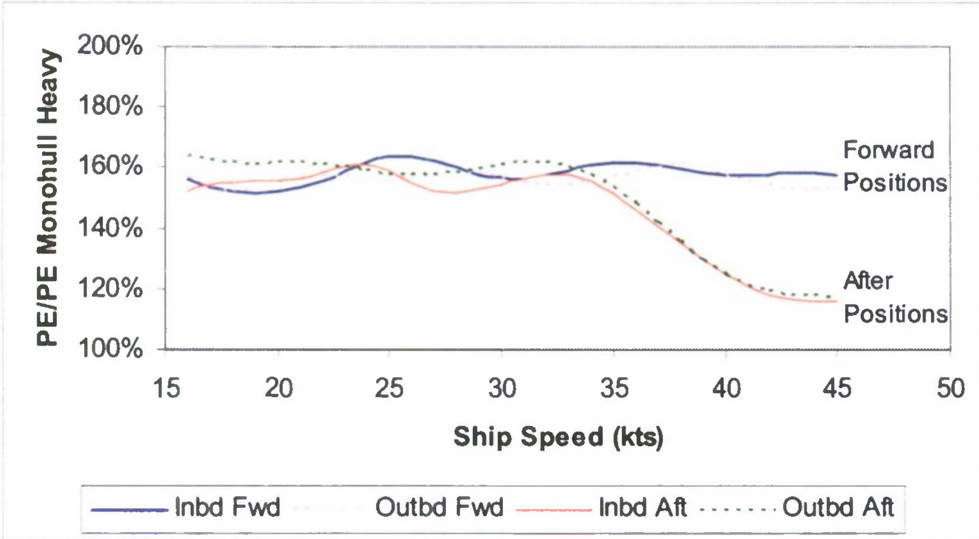

Figure 14 – Trimaran EHP penalty expressed as a percentage of center hull EHP at equivalent displacement

Figure 15 compares the EHP of the tested side hull positions referenced to that of the Outboard Aft position.

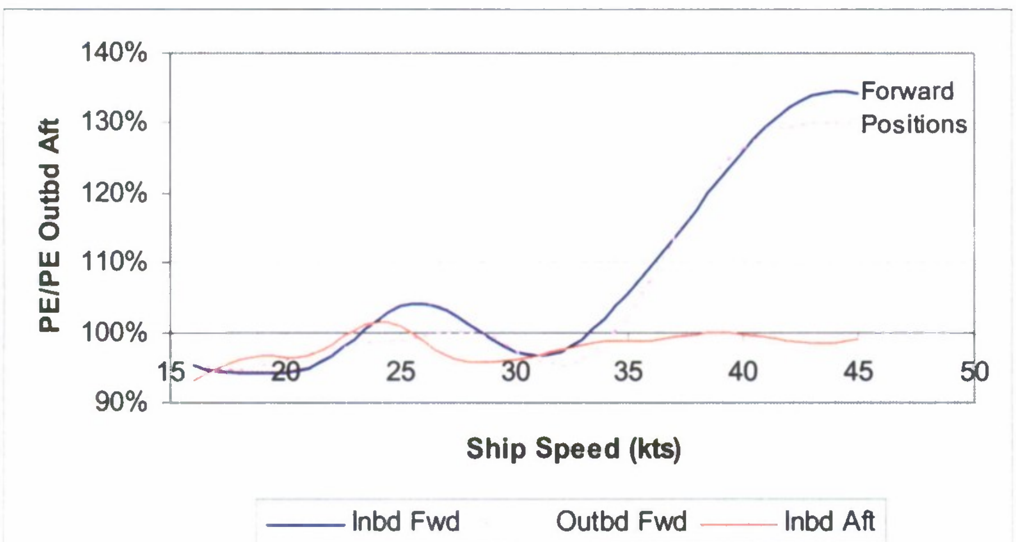

Figure 15 – Relative EHP of trimaran configurations referenced to the outboard aft side hull position

It can be seen that the inboard lateral position is marginally preferable to the outboard for both the fore and after side hull longitudinal positions. The difference is quite small, but this is a somewhat unexpected result.

Sinkage and trim for trimaran conditions was shown to vary only slightly from that measured with the center hull tested alone. The trend is for the bow to trim slightly downwards through most of the speed range, with the hull coming back to level or slightly bow up at ship speeds above 40 knots. Complete tables of EHP, Sinkage, and Trim are given in Appendices A and B.

Side Hull Angle Studies

Altering the side hulls' angle with respect to the center hull changed total trimaran EHP on the order of 5-10% as shown in Figure 16. The effects were largely negative, although small gains were evident for the 1 degree angle of attack. The best performance was obtained with the side hulls oriented 1 degree outboard. This is probably due to the narrowing of the center and side hulls aft, which causes the outboard angle to provide (in a two-dimensional sense) a constant-width rather than diverging channel. The previously observed trend for hulls without a tapering waterline is for resistance to drop as the side hulls turn inboard to reduce their angle of attack with respect to the flow from the center hull.

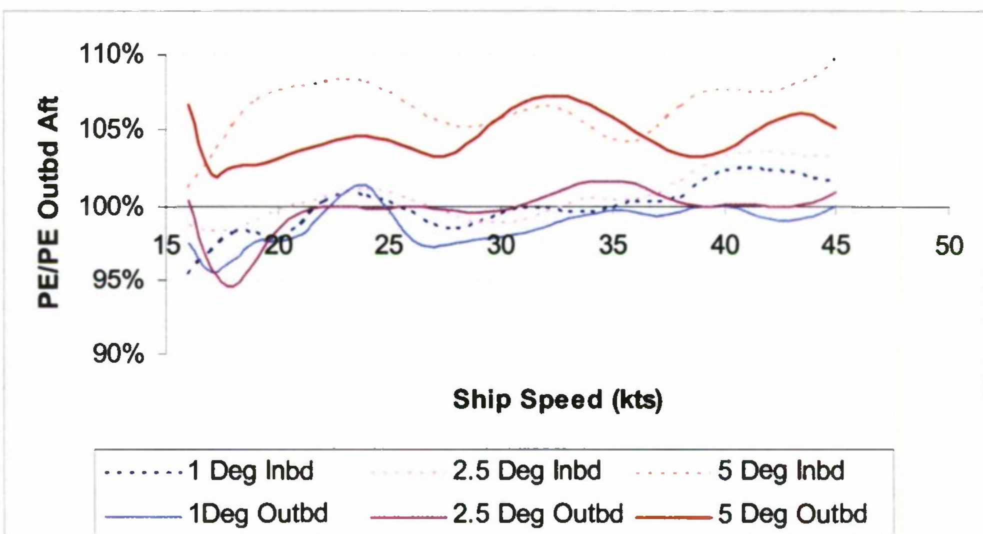

Figure 16 – Change in effective power with change in side hull angle expressed as a percentage of trimaran EHP in the outboard aft condition with no toe angle

In general, the results show greater sensitivity to the magnitude of the angle than its direction. The comparatively low sensitivity to angle when compared with previous angle studies is probably due at least in part to the use of extremely long side hulls. At high speeds, the center hull wave system creates a large trough amidships. Figure 17 shows the free surface wave elevations for a representative condition (39 knots) as predicted by the Total Ship Drag 2006 potential flow program [4] with the side hulls shown in the outboard aft position for reference. Because the side hulls extend across the trough and the following crest regardless of angle, it is not possible to 'tuck in' to a comparatively uniform region of inclined flow as it might be with a shorter hull. This same issue probably also contributes to the generally poor performance of the trimaran

configurations by forcing the side hulls to operate in a substantial wave field regardless of position.

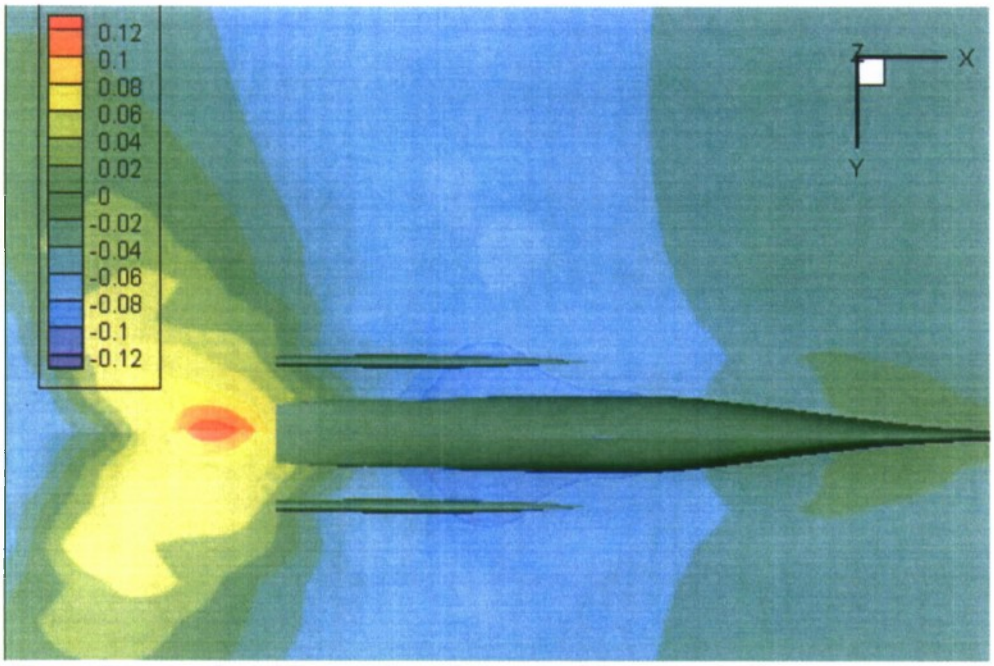

Figure 17 – Predicted free surface elevation of the center hull wave system at a ship speed of 39 knots with side hulls shown for reference

See Appendix A for tabular resistance data for variations in side hull angle.

Component Hull Studies

The center hull was tested alone in a free to sink and trim condition at a displacement of 36124.2 long tons. This varies by less than 0.15% from the design displacement condition tested during the initial series of hull form resistance tests performed with the λ=34.121 resistance model.

The side hulls tested in the catamaran configuration (per Figure 8) shown in Figure 18 a maximum EHP that is approximately 1/5 of that of the center hull. Very little difference is observed between the positions representing the inboard and outboard trimaran positions, although as observed in the trimaran tests, the inboard position in marginally superior. The difference falls within the measurement uncertainty of the catamaran model test (1.74%, See Appendix A), but is consistent across all of the catamaran and trimaran conditions tested.

The narrow spacing, typical of fast catamaran designs, shows a speed dependent interaction arising at speeds over 25 knots. This corresponds to the onset of substantial wavemaking resistance, and is typical of catamaran designs of this type. This interaction amounts to an EHP penalty of approximately 16% at 32 knots, as shown in Figure 19.

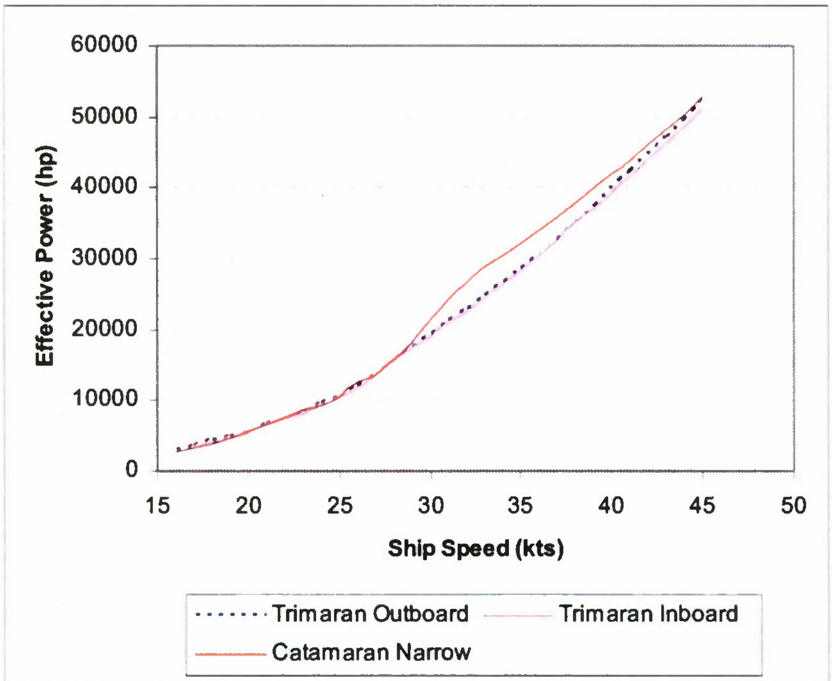

Figure 18 – Side hull effective power, hulls free to sink and trim in a catamaran configuration

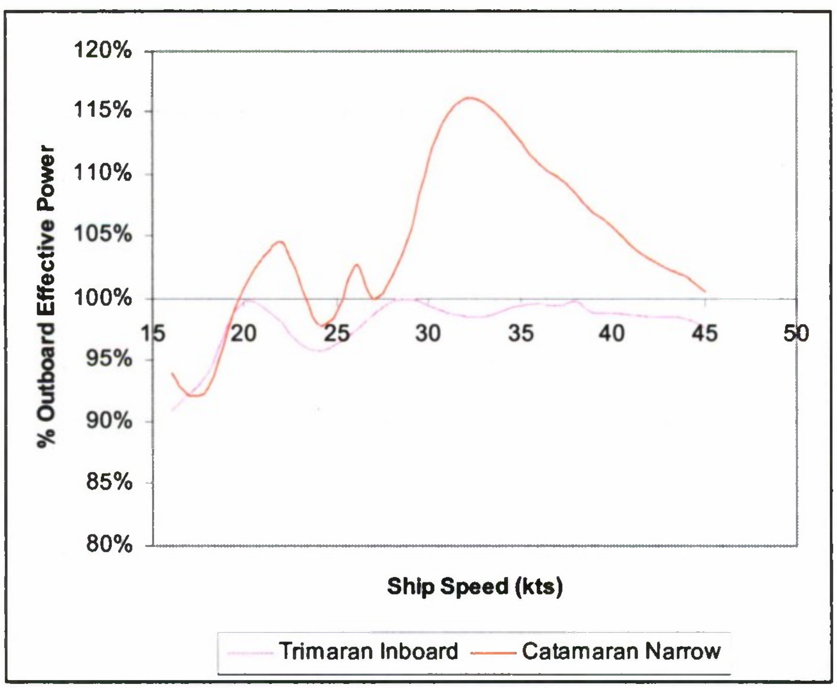

Figure 19 – Change in effective power with side hull separation distance as a percentage of the effective power of the outboard configuration

The trends in sinkage and trim for the side hulls in the catamaran condition are opposite those observed in the trimaran condition. The bows tend to rise moderately with speed. Full sinkage and trim curves for each condition are given in Appendix B, and a representative curve is given in Figure 20.

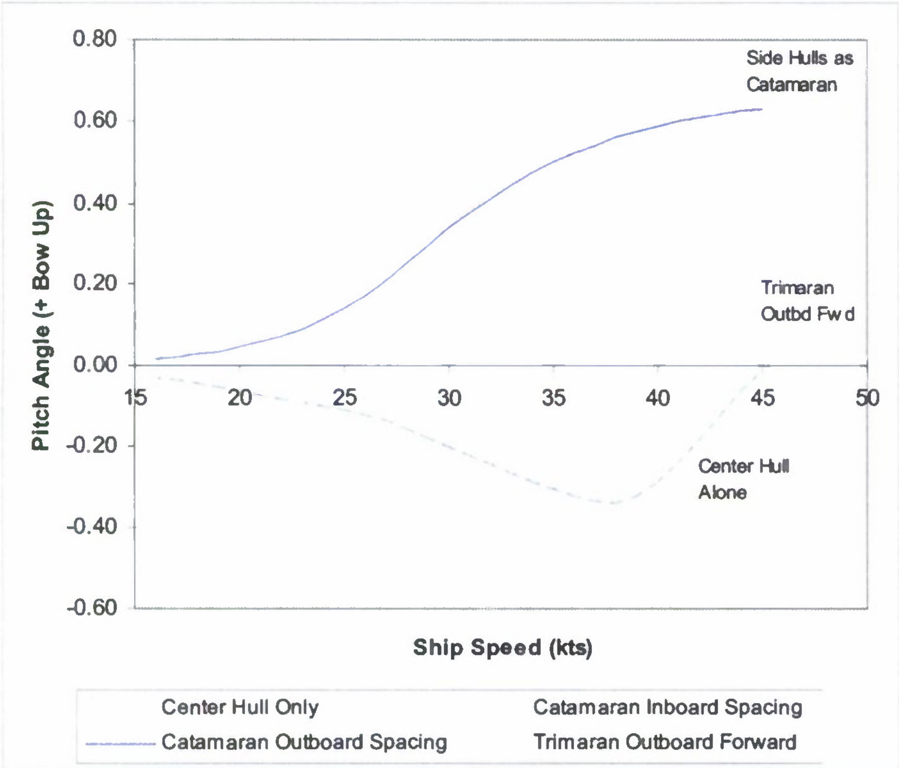

Figure 20 – Side hull running trim run in isolation and as part of a trimaran

Because the side hulls in most trimaran designs are very much smaller than the center hull, this enforced change in running trim is almost inevitable. Some portion of the apparent interaction drag of a trimaran must be due to the change in drag on the side hulls with operating trim.

To examine this effect, the side hulls were tested over a limited speed range fixed in sinkage and trim to duplicate their orientation when operating as part of the trimaran at the forward outboard position. Forcing the side hulls into the bow down trimaran attitude increased their drag across the speed range considered as shown in Figure 21.

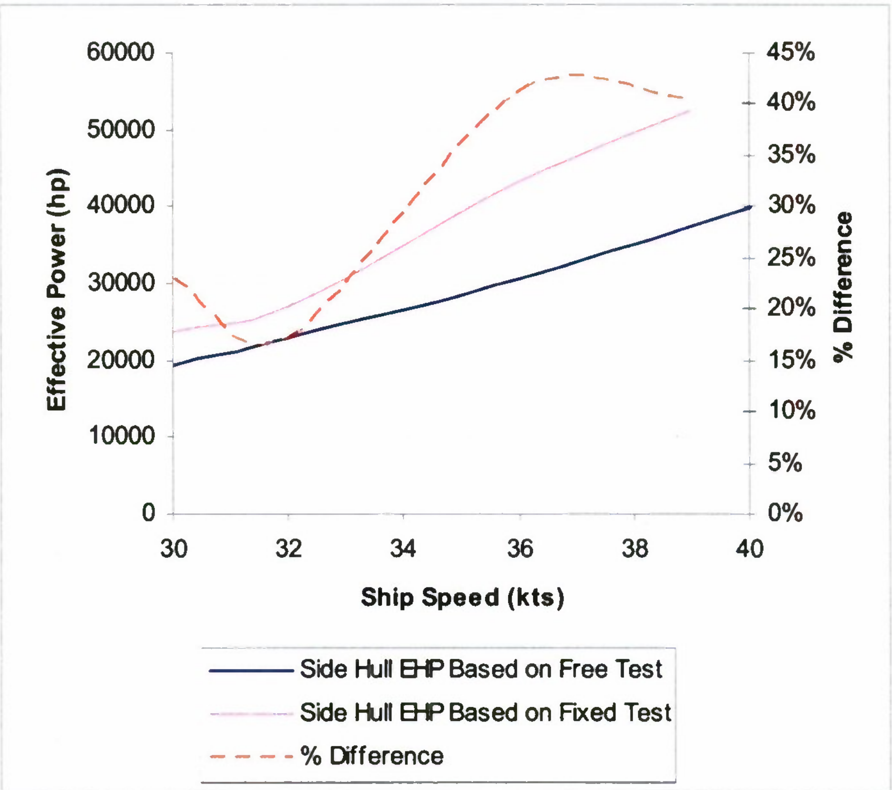

Figure 21 – Effects of constraining trim on side hull drag

This result indicates that for this design, a portion of the trimaran drag is due to the side hulls being run at a non-optimal pitch angle. From a design perspective, it indicates an area for investigation and optimization by designing side hulls to operate efficiently at their trimaran rather than individual running trim conditions.

Forces on the side hulls were also measured during the trimaran configuration test by the AMTI 6 component gauges inserted between the starboard side hull and the cross structure. (Refer to Figures 4 and 5.) This data set provides a third means of testing the side hulls' contribution to the overall drag of the trimaran. The forces measured at each gauge were summed and transformed to give overall forces in the longitudinal (drag) and transverse (side force) directions and effective power was calculated in the same manner as the separate side hull tests.

This calculation yielded effective power curves very different from those of either the free or fixed catamaran tests. As shown in Figure 22, the values for the forward positions are much higher, and the after much lower. This suggests that the primary form of interaction drag is an increase or decrease in the forces experienced by the side hulls. In fact, the vast majority of the difference in effective power between this forward and aft side hull positions is explained by the difference in side hull effective power measured in this configuration.

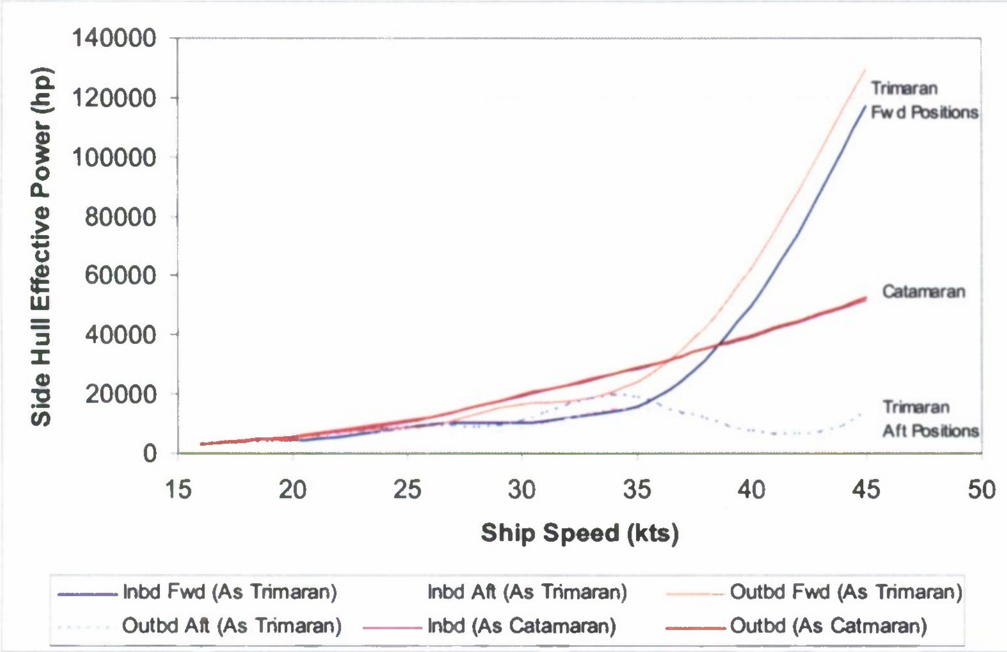

Figure 22 – Side hull effective power as measured in the trimaran configuration by force gauges attached to the starboard side hull and as measured by tests in the catamaran condition free in sinkage and trim

In fact, calculations for thc after positions show a negative value for the coefficient of residuary resistance C_R. In physical terms, this implies that the drag for the hull as a whole is less than that of an equivalent flat plate. This reduction in drag is bclieved to be the practical manifestation of wave cancellation effects. (See Apparent Interaction below.)

The effective powcr curves measured on the side hull in the trimaran configuration also show more variation with speed than the smooth approximately cubic increase normally seen. This is probably due to the changes in the center hull wave system (and hence inflow characteristics to the side hull) with speed.

The asymmetrical inflow cxperienced by the side hulls operating in the flow generated by the center hull also generates significant transverse forces on the side hulls. The net effect is analogous to an airfoil acting at an angle of attack, and properly accounting for these effects in potential flow resistance solvers has been a source of some contention. Ratios of transverse to longitudinal force (analogous to lift-drag ratio) for each trimaran configuration were calculated, and are given in tabular form in Appendix C and shown in Figure 23.

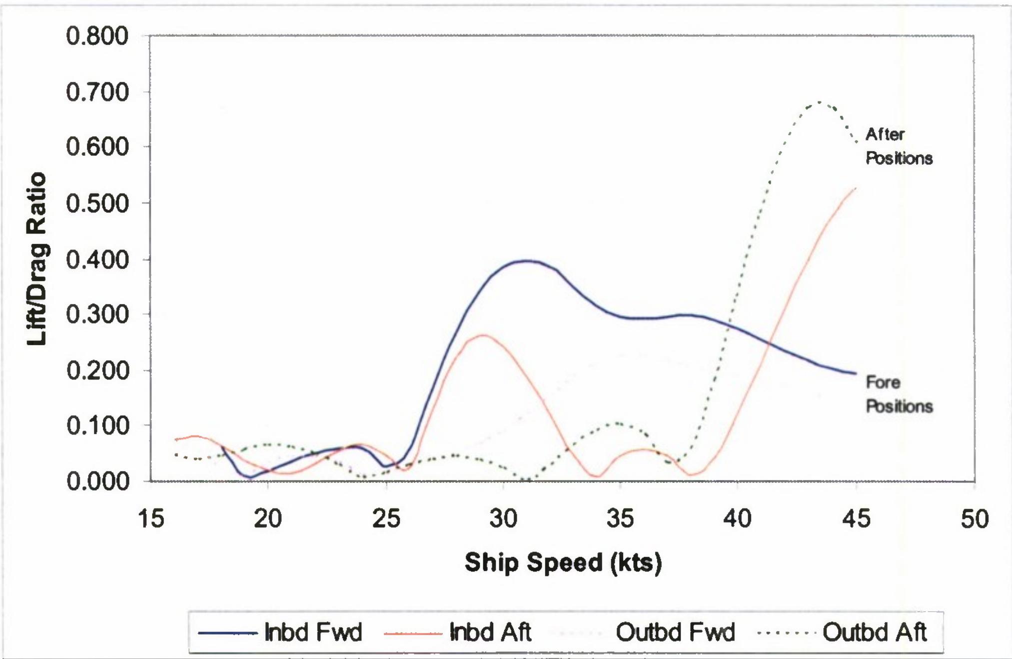

Figure 23 – Side Force to Drag ratio of side hulls measured in situ by AMTI force gauges during trimaran configuration model tests

In general terms, the lift-drag ratio for the forward side hull positions appears to achieve a peak value between 28 and 31 knots ship speed and then decrease at higher speeds. At the forward positions, an increase is evident at speeds higher than approximately 27 knots.

For the conditions with a zero toe angle, the net force on the side hulls is oriented aft at low speeds, with an inboard force component becoming increasingly significant at higher speeds. As toe angle increases, side force increases in the direction opposite the motion of the bow: inboard toe conditions lead to an outboard side force and vice versa.

Apparent Interaction

In the simplest possible formulation, trimaran interaction can be calculated by subtracting the component hull effective power from the trimaran effective power. The difference between the two quantities aggregates all the various effects into a single value:

$$Interaction = EHP_{Trimaran} - EHP_{Components}. \quad (1)$$

This interaction can be further subdivided into parts attributed to various causes:

$$Interaction = \Delta EHP_{Wave\_Interaction} + \Delta EHP_{SideHull\_Trim} + \Delta EHP_{SideHull\_Angle} + \Delta EHP_{CenterHull\_Trim} + \Delta EHP_{Viscous\_Interaction} \quad (2)$$

Side hull effective power was measured with as many as three separate methods and conditions, each of which measures a different combination of the interaction factors. Tests as a catamaran free to sink and trim compared to the trimaran provided a value for the aggregate Interaction.

A limited series of tests as a catamaran fixed in trimaran-equivalent sinkage and trim for the outboard forward condition, when compared to the free catamaran tests isolated $\Delta EHP_{SideHull\_Trim}$. The toe-in study measured $\Delta EHP_{SideHull\_Angle}$, and is set to zero for the cases discussed below as the side hulls were aligned parallel to the center hull. $\Delta EHP_{CenterHull\_Trim}$ is also set to zero, based on the very small changes to center hull trim caused by the presence of the side hulls as demonstrated in Figure 21 and Appendix B. $\Delta_{EHPWave\_Interaction}$ and $\Delta_{EHPViscous\_Interaction}$ are the most difficult to separate from each other and to measure directly, and are here found by subtraction of the measurable components from the total drag. A summary of the different components is given in Table 3.

Table 3 – Summary of Interaction Drag Components

Interaction Component	Measured By	Treatment in Data Analysis
$\Delta EHP_{SideHull\_Trim}$	Separate Free & Fixed Tests	Explicit
$\Delta EHP_{SideHull\_Angle}$	Separate Toe Angle Tests	Zero for all zero toe angle conditions. Explicit if non-zero toe angle data is considered.
$\Delta EHP_{CenterHull\_Trim}$	Separate Free & Fixed Tests	Assumed negligible based on small difference between trimaran and center hull trims
$\Delta_{EHPWave\_Interaction}$	Potential flow CFD or wake field measurements (not performed for this test series)	Found by subtraction of component hull resistance curves and explicitly treated drag components. Aggregated with $\Delta_{EHPViscous\_Interaction}$
$\Delta_{EHPViscous\_Interaction}$	Viscous CFD or wind tunnel testing	Found by subtraction of component hull resistance curves and explicitly treated drag components. Aggregated with $\Delta_{EHPViscous\_Interaction}$

This approach to interaction drag addresses the question of how to relate the massive historical database of separately measured monohull and catamaran drag data to trimaran performance and attempts to separate the effects of individual physical phenomena. Forces on the side hulls were also measured directly by force gauges, which gave the actual forces measured with the side hulls operating as an 'all-up' trimaran. The second approach shows how the interaction is experienced by the individual hulls, and provides insight for designers.

A representative breakdown of trimaran effective power using side hull measurements in the free to sink and trim catamaran condition is shown in Figure 24. The majority of the total effective power is accounted for by the center hull, and the side hull effective power is small by comparison. The lumped parameter interaction effects account for between 10 and 20 percent of the total effective power.

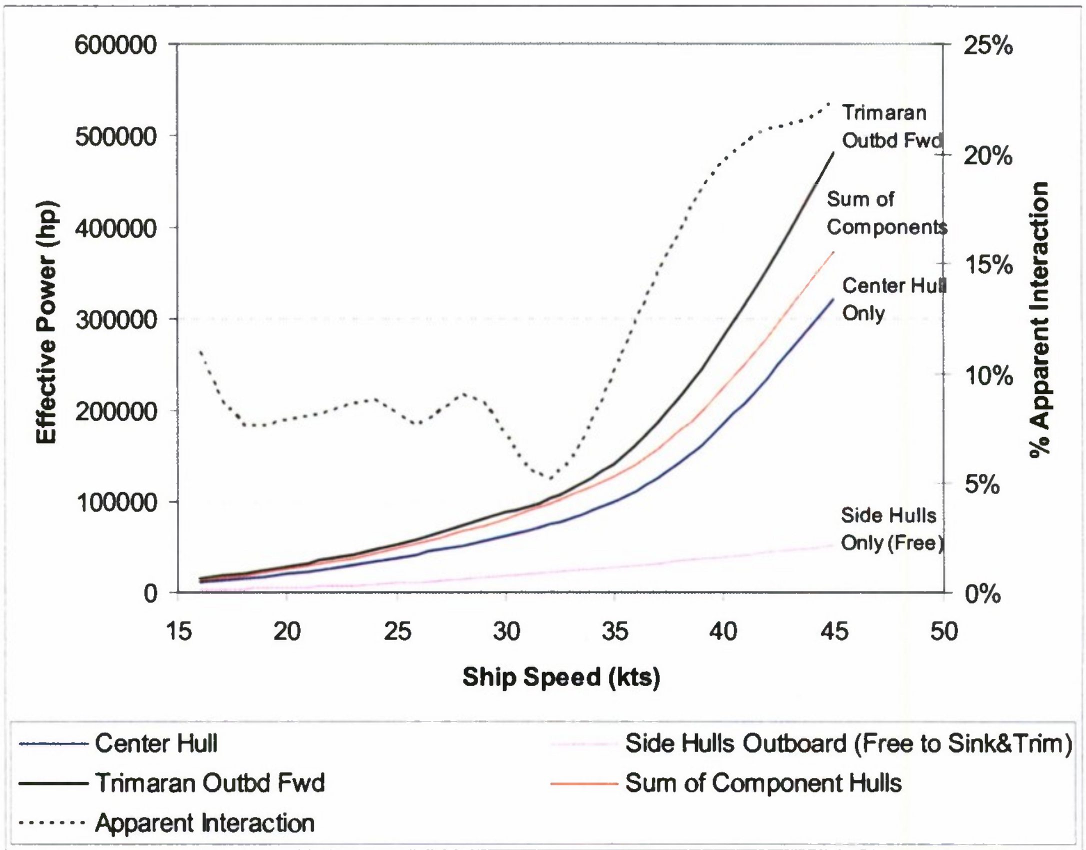

Figure 24 – Relative magnitude of drag components for the outboard forward trimaran condition and apparent interaction based on side hulls tested free in sinkage & trim

Figure 25 shows the total apparent interaction calculated in the same manner on a percentage basis for all four trimaran test conditions. This figure shows once again that the forward longitudinal position induces extremely unfavorable interactions between the component hulls. The after longitudinal position shows a small beneficial interaction at high speeds– less power is required for the trimaran than the sum of the powers of the component hulls. A breakdown of the components of drag for the Outboard Aft position is given in Figure 26 for comparison with Figure 24.

The magnitude of the apparent interaction falls into two major zones. For speeds below 35 knots (Center Hull Fn=0.33), the interaction is on the order of a 10% penalty, and does not obviously depend on either speed or side hull position. Above this speed threshold, which corresponds to the onset of substantial wave resistance, interaction changes rapidly with increasing speed and differs with longitudinal side hull position. This suggests that wave interaction is dominant at high speed, but 10% of trimaran EHP is accounted for by some combination of less dramatically speed dependent effects. Possible causes include viscous interactions between the hulls ($\Delta EHP_{Viscous\_Interactions}$), a venturi effect from channeling flow between the hulls, or trim and heave constraints ($\Delta EHP_{CenterHull\_Trim}$ and $\Delta EHP_{SideHull\_Trim}$) but the nature of these low speed interactions has never been adequately investigated.

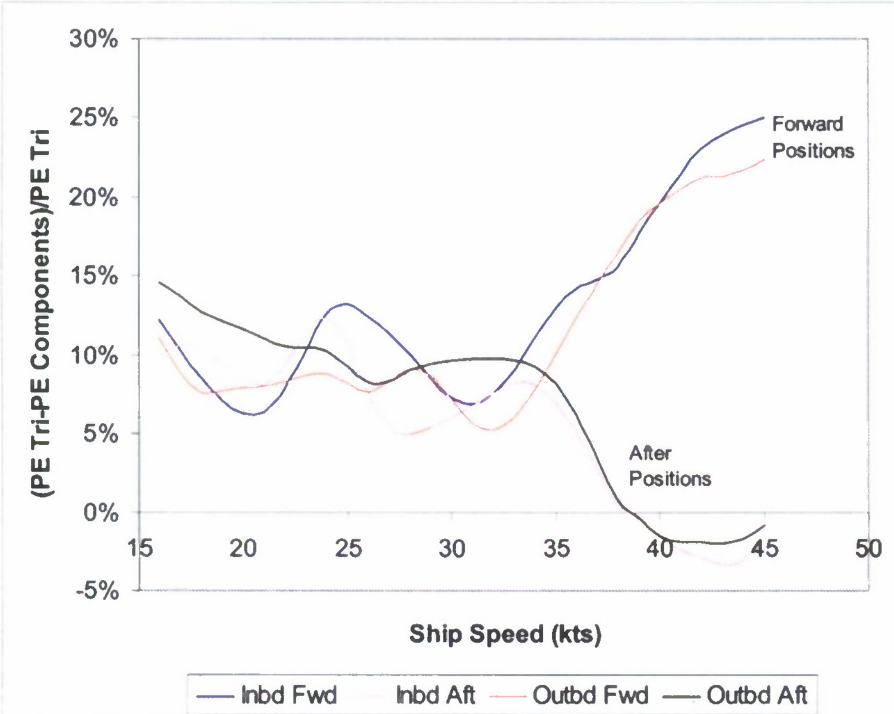

Figure 25 – Apparent interaction for trimaran test conditions for side hull EHP measured as catamarans free to sink and trim

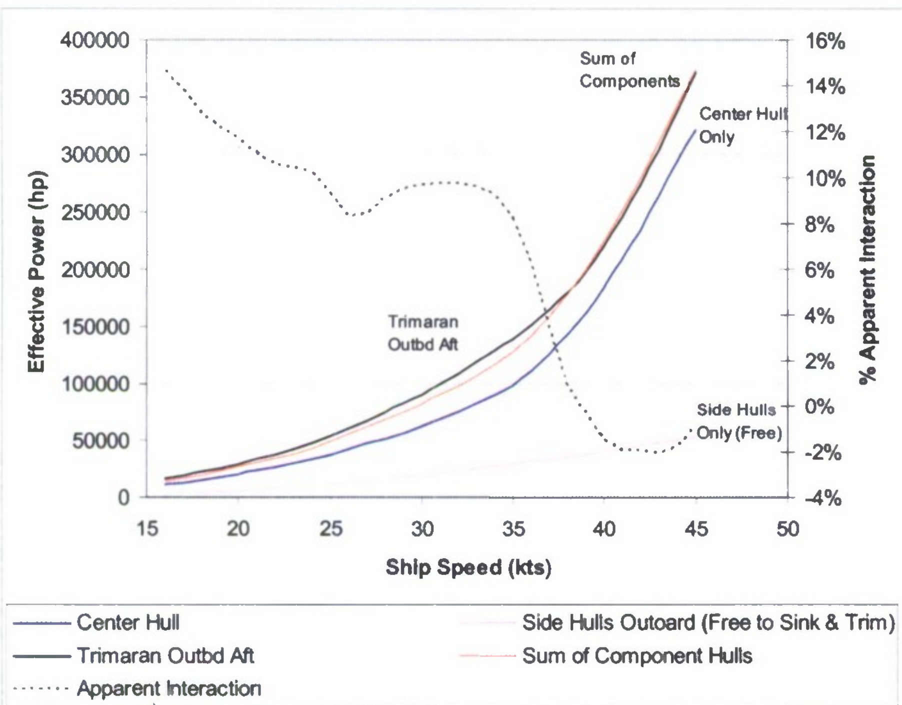

Figure 26 - Relative magnitude of drag components for the outboard aft trimaran condition and apparent interaction based on side hulls tested free in sinkage & trim

Incorporating the higher drag measured for the side hulls operating at a trimaran-equivalent pitch leads to the apparent interaction shown in Figure 27 for the outboard forward position. Interaction in this formulation is :

$$\Delta EHP_{Wave\_Interference} + \Delta EHP_{Viscous\_Interference} \qquad (3)$$

since $\Delta EHP_{SideHull\_Pitch}$ is handled explicitly. ($\Delta EHP_{CenterHull\_Trim}$ and $\Delta EHP_{SideHull\_Angle}$ are still set to zero.)

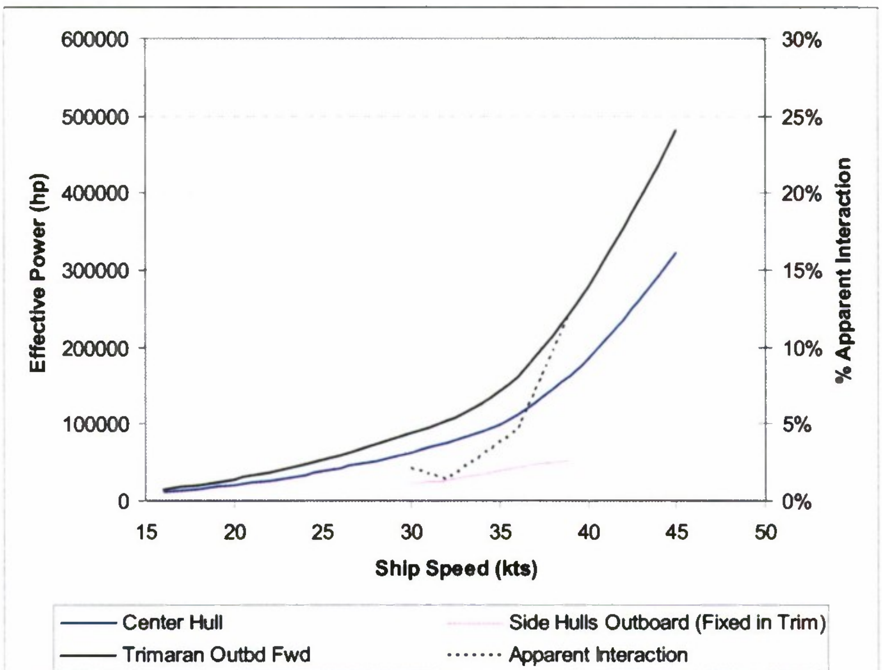

Figure 27- Relative magnitude of drag components for the outboard forward trimaran condition and apparent interaction based on side hulls tested fixed in sinkage and trim over a limited speed range

Comparison with Figure 25 shows that the apparent interference is substantially lower when the contribution of side hull pitch to interaction is formally accounted for rather than lumped into the aggregate interaction parameter. At 36 knots, for instance, the sum of the effective powers of the separately tested center hull and fixed-pitch side hulls differs from the measured trimaran effective power by only 4%.

Finally, the apparent interaction for the same forward outboard configuration calculated using the side hull drag measured during the trimaran test itself is shown in Figure 28. This method shows an approximate interaction effect of 10% of effective power through most of the speed range. Through the lower portion of the speed range, this interaction is comparable to that calculated on the basis of the side hull EHP measured in the catamaran condition, but it does not show the distinct increase in apparent interaction at the higher speed range.

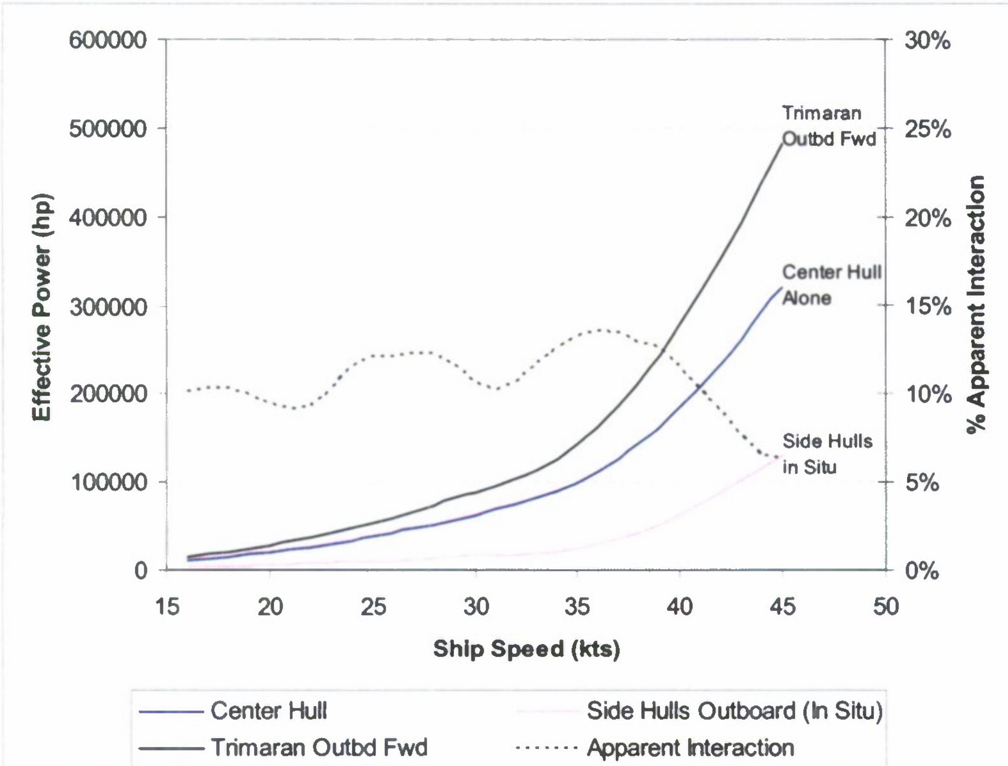

Figure 28 – Relative magnitude of drag components for the outboard forward trimaran condition and apparent interaction based on side hull drag measured by AMTI gauges during the trimaran test

Figure 29 shows interaction calculated in this fashion for all four side hull positions. The direct measurement of side hull drag aggregates the effect of each drag component on the side hulls.

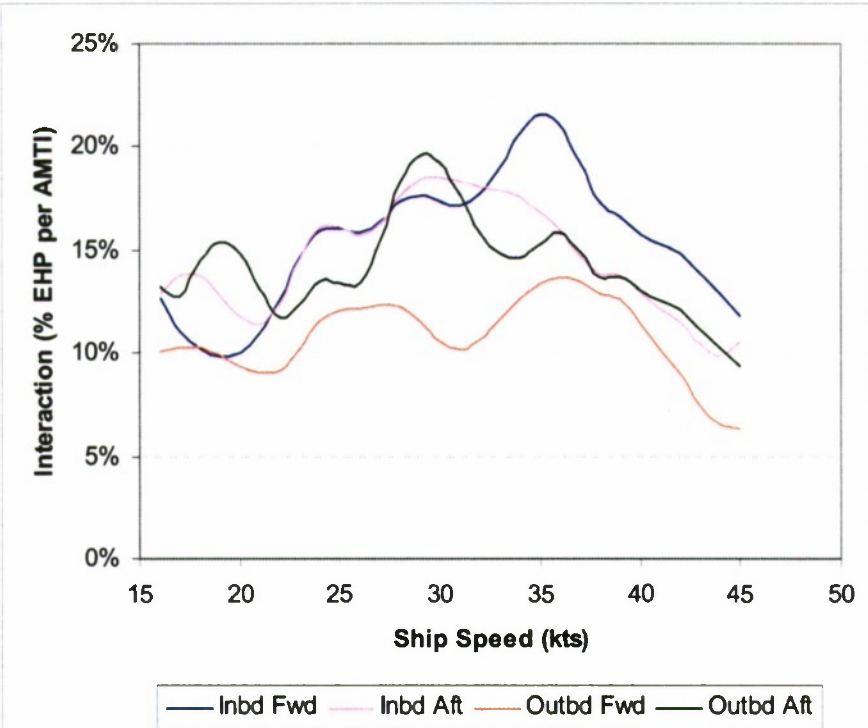

Figure 29 – Apparent interaction for trimaran test conditions for side hull EHP measured in situ in the trimaran configuration

This, in combination with the large differences in side hull EHP with position shown in Figure 22, suggests that there is an effective horsepower penalty of 10-15% for the trimaran which does not strongly depend on side hull position or speed. This could be due to an increase in the drag of the center hull due to wake wash from the side hulls – the peaks in the 30-35 knot region shown in Figure 29 correspond to a Froude range based on side hull length of 0.42-0.5, which is in the peak wavemaking regime for the side hulls.

At higher speeds, the drag of the side hulls in the trimaran deviates significantly from that measured as a catamaran, and depends very strongly on position. For the catamaran, fixing the side hulls in a trimaran-equivalent sinkage and trim condition raises their effective power and consequently lowers the apparent interaction, but the result is not consistent with the side hull measurements made in the trimaran configuration.

For reference, Figure 30 shows the percent of EHP due to interaction effects calculated by all three methods at the forward outboard side hull position.

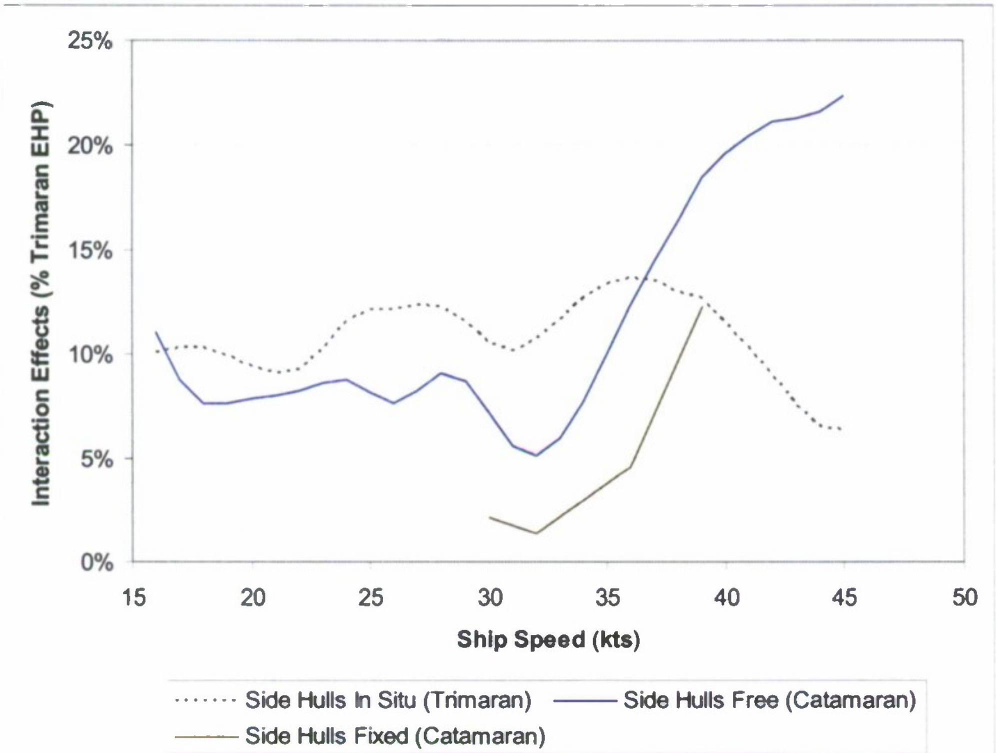

Figure 30 – Interaction effects expressed as a percentage of trimaran effective power as calculated using the side hull effective power measured in the trimaran, catamaran free to sink and trim, and catamaran fixed in sinkage and trim conditions.

Dynamic Wetted Surface Survey

It has been postulated that some portion of the interaction drag is due to wave wash from the center hull increasing the wetted surface of the side hulls. Resistance calculations for displacement hull vessels are customarily carried out using the still water wetted surface area. A related possibility is that the local flow velocity is greater than the ship speed, which would change the side hull Reynolds Number from that used to calculate the frictional drag coefficient C_F, although this phenomenon would be difficult to rigorously measure and test.

A dynamic wetted surface survey was conducted at the 39 knot ship speed for all conditions tested, as reported in Table 3. The maximum deviation from the static wetted surface area is 6.8%, which occurred in a catamaran rather than a trimaran configuration.

Table 4 – Dynamic wetted surface Area at 39 knot ship speed

Condition	Trimaran Inboard Forward	Trimaran Outboard Forward	Trimaran Inboard Aft	Trimaran Outboard Aft	Center Hull Alone	Cat per Inboard Position	Cat per Outboard Position
% of Static Wetted Surface	104.7%	96.25%	102.2%	101.9%	103.1%	94.2%	93.2%

These differences proved to be comparatively minor. Recalculating ship scale EHP led to a change of no more than 1.8% for any trimaran configuration. For the outboard forward condition, interaction calculated using both corrected side hull trim and dynamic wetted surface area was 14.3% of trimaran EHP, as compared to 12.3% for side hull trim and static wetted surface. Measuring wetted surface is labor intensive, and this difference is small compared to the 15% change in apparent interaction by taking side hull trim into account.

The wave traces constructed in order to estimate wetted surface are, however, valuable for diagnosing unfavorable wave interactions. The size and extend of peaks and troughs offer insight into the behavior of the wave systems between the hulls.

Conclusions

Several conclusions can be drawn from the results of this experiment:

- In all cases it would be substantially more efficient to operate as a monohull at equivalent displacement. This is a natural consequence of a center hull design intended for use as a monohull. A modified center hull that increased fineness and slenderness at the expense of transverse stability might reduce wavemaking drag to the point that the friction drag penalty of the side hulls was a worthwhile investment. The penalties might be worthwhile if an extremely high vertical center of gravity (as, for example, in a ship with extensive aviation facilities at and just below the weather deck) required extremely high transverse stability to operate safely.

- Some wave cancellation was observed for configurations placing the side hulls in the aft position. The forward side hull position created very unfavorable wave interactions and led to a large increase in interaction drag.

- Changing the angle of the side hulls relative to the main hull affected the total drag, but did not offer the significant improvements suggested by previous experiments. This is probably due to the side hulls' extreme length relative to the center hull. This caused the side hulls to span a crest and trough of the center hull wave system regardless of their angle, and prevented them from operating in a quasi-uniform inflow. Angular variation may still be valuable in reducing the drag for trimaran designs featuring shorter side hulls.

- At ship speeds greater than approximately 30 knots, the primary manifestation of interaction between the component hulls is a large change in side hull drag. This can be either an increase or decrease depending on longitudinal position. In the after position, a negative coefficient of residuary resistance was measured for the side hulls.

- An EHP penalty of 10-15% appears to be independent of ship speed and side hull position. The physical effects driving this component of the interaction between the component hulls are judged not to be wavemaking related.

- Use of dynamic wetted surface in resistance calculations has a comparatively minor effect on the overall results.

- Forcing the side hulls to operate at a trim imposed by the presence of the center hull can have a significant effect on their drag. This effect should be taken into account when attempting to predict the behavior of a known monohull or catamaran design in a trimaran configuration.

- The results taken as a whole reinforce the notion that the central problem of trimaran design for resistance and propulsion is to place the side hulls in a longitudinal position that minimizes their contribution to trimaran drag. The side hulls should be as small as is consistent with the need to stabilize the center hull in transverse roll, and preferably short enough to avoid spanning a crest and trough of the center hull wave system at the desired sustained speed. Attention to the trim at which the side hulls will operate in the presence of the center hull may yield additional reductions in trimaran drag.

Acknowledgments

The author would like to thank Andrew Collins and Sean Tzeng for their assistance in performing the test. Valuable assistance with instrumentation and data collection software were provided by Dennis Mullinix, Don Walker and Jason Carneal. Charles Crump and the rest of Code 5104 provided carriage operators and facilities support for extended testing hours.

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Apendix A – Effective Power

Table A.1 – Effective Power for the fully appended Center Hull free to sink and trim

Experiment Name JHSS Trimaran Center Hull (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	110655.9	ft^2	48.98	ft^2
Δ	36124.2	LT	732.55	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	(kW)	Frictional Power (hp)	(kW)	Froude Number	V-L	1000CR
16.0	10824.1	8071.5	5529.7	4123.5	0.152	0.512	1.343
17.0	12765.8	9519.4	6585.1	4910.5	0.162	0.544	1.307
18.0	14945.9	11145.2	7764.3	5789.8	0.171	0.576	1.279
19.0	17451.0	13013.2	9073.6	6766.2	0.181	0.608	1.269
20.0	20258.4	15106.7	10519.5	7844.4	0.190	0.640	1.264
21.0	23270.8	17353.0	12108.3	9029.1	0.200	0.672	1.252
22.0	26391.4	19680.0	13846.3	10325.2	0.209	0.704	1.224
23.0	29573.8	22053.2	15739.9	11737.2	0.219	0.736	1.181
24.0	33134.5	24708.4	17795.3	13270.0	0.228	0.768	1.153
25.0	37513.9	27974.1	20018.8	14928.0	0.238	0.800	1.163
26.0	42362.5	31589.7	22416.6	16716.1	0.247	0.832	1.179
27.0	46983.9	35035.9	24994.9	18638.7	0.257	0.864	1.160
28.0	51578.0	38461.7	27759.8	20700.5	0.267	0.896	1.127
29.0	56750.2	42318.6	30717.6	22906.1	0.276	0.928	1.109
30.0	62525.8	46625.5	33874.2	25260.0	0.286	0.960	1.102
31.0	68665.2	51203.6	37235.9	27766.8	0.295	0.992	1.096
32.0	75118.7	56016.0	40808.7	30431.0	0.305	1.024	1.088
33.0	81983.4	61135.0	44598.6	33257.2	0.314	1.056	1.081
34.0	89735.0	66915.4	48611.7	36249.7	0.324	1.088	1.087
35.0	99122.7	73915.8	52854.1	39413.3	0.333	1.120	1.121
36.0	111089.8	82839.7	57331.6	42752.2	0.343	1.152	1.197
37.0	126423.7	94274.2	62050.4	46271.0	0.352	1.184	1.320
38.0	143890.3	107298.9	67016.4	49974.1	0.362	1.216	1.455
39.0	162161.8	120924.0	72235.5	53866.0	0.371	1.248	1.575
40.0	184150.9	137321.3	77713.7	57951.1	0.381	1.280	1.727
41.0	208184.5	155243.2	83456.8	62233.7	0.390	1.312	1.880
42.0	234342.2	174748.9	89470.9	66718.4	0.400	1.344	2.031
43.0	263490.0	196484.4	95761.8	71409.5	0.409	1.376	2.191
44.0	293372.5	218767.9	102335.3	76311.4	0.419	1.408	2.329
45.0	321416.6	239680.3	109197.4	81428.5	0.428	1.440	2.419

Table A.2 – Effective Power for Side Hulls in a free to sink and trim catamaran configuration at a narrow (S/LWL=0.19) transverse centerline spacing

Experiment Name JHSS Trimaran Side Hulls Narrow Spacing (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.9	ft^2	12.25	ft^2
Δ	4010.47	LT	81.33	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
C_A			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	2775.6	2069.7	1522.7	1135.5	0.226	0.761	1.271
17.0	3303.5	2463.4	1812.7	1351.7	0.241	0.809	1.261
18.0	3953.0	2947.8	2136.5	1593.2	0.255	0.857	1.294
19.0	4731.3	3528.1	2496.1	1861.3	0.269	0.904	1.354
20.0	5628.8	4197.4	2893.0	2157.3	0.283	0.952	1.421
21.0	6672.8	4975.9	3329.0	2482.4	0.297	0.999	1.500
22.0	7768.4	5792.9	3805.8	2838.0	0.311	1.047	1.546
23.0	8618.8	6427.0	4325.2	3225.3	0.326	1.094	1.466
24.0	9361.2	6980.6	4888.8	3645.6	0.340	1.142	1.344
25.0	10613.6	7914.6	5498.4	4100.2	0.354	1.190	1.360
26.0	12455.3	9287.9	6155.7	4590.3	0.368	1.237	1.489
27.0	13756.9	10258.5	6862.3	5117.2	0.382	1.285	1.455
28.0	15840.4	11812.2	7619.8	5682.1	0.396	1.332	1.556
29.0	18406.0	13725.4	8430.1	6286.3	0.410	1.380	1.699
30.0	21456.3	15999.9	9294.7	6931.0	0.425	1.428	1.871
31.0	24279.2	18105.0	10215.2	7617.5	0.439	1.475	1.961
32.0	26707.5	19915.7	11193.5	8347.0	0.453	1.523	1.967
33.0	28772.8	21455.9	12231.0	9120.6	0.467	1.570	1.912
34.0	30561.7	22789.8	13329.4	9939.7	0.481	1.618	1.821
35.0	32225.3	24030.4	14490.4	10805.5	0.495	1.666	1.718
36.0	33991.2	25347.2	15715.6	11719.1	0.510	1.713	1.627
37.0	36019.7	26859.9	17006.6	12681.9	0.524	1.761	1.559
38.0	38043.3	28368.9	18365.1	13694.9	0.538	1.808	1.490
39.0	40043.6	29860.5	19792.6	14759.4	0.552	1.856	1.418
40.0	42033.5	31344.4	21290.8	15876.6	0.566	1.903	1.346
41.0	44033.2	32835.6	22861.3	17047.6	0.580	1.951	1.276
42.0	46071.6	34355.6	24505.6	18273.8	0.594	1.999	1.209
43.0	48186.9	35933.0	26225.4	19556.3	0.609	2.046	1.148
44.0	50428.1	37604.2	28022.3	20896.2	0.623	2.094	1.093
45.0	52855.9	39414.7	29897.8	22294.8	0.637	2.141	1.047

Table A.3 – Effective Power for Side Hulls in a free to sink and trim catamaran configuration at a transverse centerline spacing equivalent to the inboard trimaran position

Experiment Name	JHSS Trimaran Side Hulls Inboard Spacing (PE from CR Input)			
	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.9	ft^2	12.25	ft^2
Δ	4010.47	LT	81.33	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	2684.2	2001.6	1522.7	1135.5	0.226	0.761	1.178
17.0	3310.8	2468.9	1812.7	1351.7	0.241	0.809	1.267
18.0	4006.2	2987.4	2136.5	1593.2	0.255	0.857	1.332
19.0	4763.4	3552.0	2496.1	1861.3	0.269	0.904	1.373
20.0	5572.3	4155.3	2893.0	2157.3	0.283	0.952	1.391
21.0	6419.4	4786.9	3329.0	2482.4	0.297	0.999	1.386
22.0	7287.6	5434.3	3805.8	2838.0	0.311	1.047	1.358
23.0	8179.8	6099.7	4325.2	3225.3	0.326	1.094	1.316
24.0	9158.5	6829.5	4888.8	3645.6	0.340	1.142	1.283
25.0	10329.9	7703.0	5498.4	4100.2	0.354	1.190	1.285
26.0	11815.9	8811.1	6155.7	4590.3	0.368	1.237	1.338
27.0	13592.3	10135.8	6862.3	5117.2	0.382	1.285	1.420
28.0	15531.5	11581.8	7619.8	5682.1	0.396	1.332	1.497
29.0	17440.9	13005.6	8430.1	6286.3	0.410	1.380	1.535
30.0	19226.5	14337.2	9294.7	6931.0	0.425	1.428	1.528
31.0	20935.5	15611.6	10215.2	7617.5	0.439	1.475	1.495
32.0	22659.6	16897.3	11193.5	8347.0	0.453	1.523	1.454
33.0	24487.5	18260.3	12231.0	9120.6	0.467	1.570	1.417
34.0	26430.3	19709.1	13329.4	9939.7	0.481	1.618	1.385
35.0	28486.0	21242.0	14490.4	10805.5	0.495	1.666	1.356
36.0	30540.2	22773.8	15715.6	11719.1	0.510	1.713	1.320
37.0	32650.1	24347.2	17006.6	12681.9	0.524	1.761	1.283
38.0	35047.4	26134.8	18365.1	13694.9	0.538	1.808	1.263
39.0	37055.8	27632.5	19792.6	14759.4	0.552	1.856	1.209
40.0	39284.6	29294.5	21290.8	15876.6	0.566	1.903	1.168
41.0	41674.6	31076.7	22861.3	17047.6	0.580	1.951	1.134
42.0	44016.0	32822.7	24505.6	18273.8	0.594	1.999	1.094
43.0	46416.4	34612.7	26225.4	19556.3	0.609	2.046	1.055
44.0	48805.5	36394.2	28022.3	20896.2	0.623	2.094	1.014
45.0	51328.3	38275.5	29897.8	22294.8	0.637	2.141	0.977

Table A.4 – Effective Power for Side Hulls in a free to sink and trim catamaran configuration at a transverse centerline spacing equivalent to the outboard trimaran position

Experiment Name	JHSS Trimaran Side Hulls Outboard Spacing (PE from CR Input)			
	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.9	ft^2	12.25	ft^2
Δ	4010.47	LT	81.33	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	(kW)	Frictional Power (hp)	(kW)	Froude Number	V-L	1000CR
16.0	2954.0	2202.8	1522.7	1135.5	0.226	0.761	1.452
17.0	3586.6	2674.5	1812.7	1351.7	0.241	0.809	1.500
18.0	4263.4	3179.2	2136.5	1593.2	0.255	0.857	1.515
19.0	4867.8	3629.9	2496.1	1861.3	0.269	0.904	1.436
20.0	5577.4	4159.1	2893.0	2157.3	0.283	0.952	1.394
21.0	6456.6	4814.7	3329.0	2482.4	0.297	0.999	1.403
22.0	7424.9	5536.8	3805.8	2838.0	0.311	1.047	1.412
23.0	8484.2	6326.6	4325.2	3225.3	0.326	1.094	1.420
24.0	9550.2	7121.6	4888.8	3645.6	0.340	1.142	1.401
25.0	10714.9	7990.1	5498.4	4100.2	0.354	1.190	1.387
26.0	12116.7	9035.4	6155.7	4590.3	0.368	1.237	1.409
27.0	13753.9	10256.3	6862.3	5117.2	0.382	1.285	1.455
28.0	15562.2	11604.8	7619.8	5682.1	0.396	1.332	1.503
29.0	17437.8	13003.4	8430.1	6286.3	0.410	1.380	1.534
30.0	19306.3	14396.7	9294.7	6931.0	0.425	1.428	1.540
31.0	21158.2	15777.7	10215.2	7617.5	0.439	1.475	1.526
32.0	22995.5	17147.8	11193.5	8347.0	0.453	1.523	1.496
33.0	24830.5	18516.1	12231.0	9120.6	0.467	1.570	1.457
34.0	26687.9	19901.2	13329.4	9939.7	0.481	1.618	1.412
35.0	28607.4	21332.5	14490.4	10805.5	0.495	1.666	1.368
36.0	30642.1	22849.8	15715.6	11719.1	0.510	1.713	1.329
37.0	32810.9	24467.1	17006.6	12681.9	0.524	1.761	1.296
38.0	35097.7	26172.4	18365.1	13694.9	0.538	1.808	1.267
39.0	37477.4	27946.9	19792.6	14759.4	0.552	1.856	1.239
40.0	39731.4	29627.7	21290.8	15876.6	0.566	1.903	1.197
41.0	42205.5	31472.6	22861.3	17047.6	0.580	1.951	1.166
42.0	44622.3	33274.9	24505.6	18273.8	0.594	1.999	1.128
43.0	47046.4	35082.5	26225.4	19556.3	0.609	2.046	1.088
44.0	49532.0	36936.0	28022.3	20896.2	0.623	2.094	1.049
45.0	52513.9	39159.6	29897.8	22294.8	0.637	2.141	1.031

Table A. 5 – Effective Power for Side Hulls fixed in sinkage and trim at conditions equivalent to those measured in the free to sink and trim catamaran configuration (Table A.4 above)

Experiment Name	JHSS Trimaran Cat Outboard Fixed per Cat (PE from CR Input)			
	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.9	ft^2	12.25	ft^2
Δ	4010.47	LT	81.33	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	0.000012814	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	(kW)	Frictional Power (hp)	(kW)	Froude Number	V-L	1000CR
30.0	18241.8	13602.9	9294.7	6931.0	0.425	1.428	1.377
36.0	28335.5	21129.8	15715.6	11719.1	0.510	1.713	1.124
39.0	37035.4	27617.3	19792.6	14759.4	0.552	1.856	1.208
40.0	39032.2	29106.3	21290.8	15876.6	0.566	1.903	1.152
44.0	50578.3	37716.3	28022.3	20896.2	0.623	2.094	1.100

Table A. 6 – Effective Power for Side Hulls fixed in sinkage and trim at conditions equivalent to those measured in the outboard forward trimaran configuration (Table A.8 below)

Experiment Name	JHSS Trimaran Cat Outboard Fixed per Tri Inbd Fwd (PE from CR Input)			
	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.9	ft^2	12.25	ft^2
Δ	4010.47	LT	81.33	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	(kW)	Frictional Power (hp)	(kW)	Froude Number	V-L	1000CR
30.0	23737.5	17701.1	9294.7	6931.0	0.425	1.428	2.222
32.0	26914.9	20070.5	11193.5	8347.0	0.453	1.523	1.993
36.0	43280.6	32274.3	15715.6	11719.1	0.510	1.713	2.454
39.0	52655.0	39264.9	19792.6	14759.4	0.552	1.856	2.301

Table A.7 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the inboard forward position

Experiment Name JHSS Trimaran Inbd Fwd (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	15387.4	11474.4	6912.2	5154.4	0.152	0.512	1.719
17.0	17909.7	13355.3	8231.6	6138.3	0.162	0.544	1.637
18.0	20721.4	15451.9	9705.6	7237.4	0.171	0.576	1.570
19.0	23912.7	17831.7	11342.3	8457.9	0.181	0.608	1.523
20.0	27556.2	20548.7	13149.6	9805.7	0.190	0.640	1.496
21.0	31737.2	23666.5	15135.7	11286.7	0.200	0.672	1.490
22.0	36554.6	27258.8	17308.3	12906.8	0.209	0.704	1.502
23.0	42116.2	31406.1	19675.3	14671.9	0.219	0.736	1.533
24.0	48395.9	36088.8	22244.6	16587.8	0.228	0.768	1.572
25.0	55134.0	41113.4	25024.1	18660.5	0.238	0.800	1.601
26.0	61899.6	46158.5	28021.4	20895.5	0.247	0.832	1.602
27.0	68345.7	50965.4	31244.3	23298.9	0.257	0.864	1.566
28.0	74613.2	55639.1	34700.5	25876.2	0.267	0.896	1.511
29.0	81055.5	60443.1	38397.8	28633.2	0.276	0.928	1.453
30.0	88146.5	65730.8	42343.7	31575.7	0.286	0.960	1.410
31.0	96248.8	71772.7	46545.8	34709.2	0.295	0.992	1.386
32.0	105761.9	78866.7	51011.9	38039.6	0.305	1.024	1.388
33.0	117152.0	87360.2	55749.4	41572.3	0.314	1.056	1.420
34.0	130722.4	97479.7	60765.9	45313.1	0.324	1.088	1.479
35.0	146670.7	109372.3	66069.0	49267.6	0.333	1.120	1.562
36.0	165184.7	123178.2	71666.1	53441.4	0.343	1.152	1.666
37.0	186739.2	139251.4	77564.7	57840.0	0.352	1.184	1.791
38.0	212146.6	158197.7	83772.3	62469.0	0.362	1.216	1.944
39.0	242374.8	180738.8	90296.3	67333.9	0.371	1.248	2.130
40.0	277873.8	207210.5	97144.1	72440.4	0.381	1.280	2.346
41.0	318016.6	237144.9	104323.2	77793.8	0.390	1.312	2.576
42.0	361746.2	269754.1	111841.0	83399.8	0.400	1.344	2.803
43.0	407589.9	303939.7	119704.7	89263.8	0.409	1.376	3.009
44.0	453607.2	338254.8	127921.8	95391.3	0.419	1.408	3.177
45.0	497335.0	370862.7	136499.6	101787.7	0.428	1.440	3.290

Table A.8 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard forward position

Experiment Name JHSS Trimaran Outbd Fwd (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed	Effective Power		Frictional Power		Froude	V-L	1000CR
(kts)	(hp)	(kW)	(hp)	(kW)	Number		
16.0	15488.0	11549.4	6912.2	5154.4	0.152	0.512	1.740
17.0	17927.2	13368.3	8231.6	6138.3	0.162	0.544	1.640
18.0	20793.9	15506.0	9705.6	7237.4	0.171	0.576	1.580
19.0	24168.4	18022.4	11342.3	8457.9	0.181	0.608	1.554
20.0	28036.7	20907.0	13149.6	9805.7	0.190	0.640	1.546
21.0	32318.1	24099.6	15135.7	11286.7	0.200	0.672	1.542
22.0	36867.0	27491.7	17308.3	12906.8	0.209	0.704	1.526
23.0	41663.0	31068.1	19675.3	14671.9	0.219	0.736	1.502
24.0	46816.1	34910.8	22244.6	16587.8	0.228	0.768	1.477
25.0	52507.9	39155.1	25024.1	18660.5	0.238	0.800	1.462
26.0	58981.9	43982.8	28021.4	20895.5	0.247	0.832	1.464
27.0	66212.4	49374.6	31244.3	23298.9	0.257	0.864	1.476
28.0	73834.2	55058.1	34700.5	25876.2	0.267	0.896	1.481
29.0	81280.1	60610.6	38397.8	28633.2	0.276	0.928	1.461
30.0	88146.9	65731.1	42343.7	31575.7	0.286	0.960	1.410
31.0	95183.0	70978.0	46545.8	34709.2	0.295	0.992	1.357
32.0	103465.8	77154.4	51011.9	38039.6	0.305	1.024	1.330
33.0	113603.2	84713.9	55749.4	41572.3	0.314	1.056	1.338
34.0	126195.2	94103.7	60765.9	45313.1	0.324	1.088	1.383
35.0	141959.4	105859.1	66069.0	49267.6	0.333	1.120	1.471
36.0	161743.5	120612.1	71666.1	53441.4	0.343	1.152	1.604
37.0	186283.9	138911.9	77564.7	57840.0	0.352	1.184	1.783
38.0	214155.7	159695.9	83772.3	62469.0	0.362	1.216	1.974
39.0	244928.6	182643.2	90296.3	67333.9	0.371	1.248	2.166
40.0	278542.4	207709.0	97144.1	72440.4	0.381	1.280	2.355
41.0	314865.9	234795.4	104323.2	77793.8	0.390	1.312	2.538
42.0	353686.6	263744.0	111841.0	83399.8	0.400	1.344	2.712
43.0	394701.0	294328.5	119704.7	89263.8	0.409	1.376	2.874
44.0	437503.5	326246.3	127921.8	95391.3	0.419	1.408	3.020
45.0	481575.8	359111.0	136499.6	101787.7	0.428	1.440	3.147

Table A.9 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the inboard aft position

Experiment Name	JHSS Trimaran Inbd Aft (PE from CR Input)			
	Ship		**Model**	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	15012.6	11194.9	6912.2	5154.4	0.152	0.512	1.643
17.0	17986.2	13412.3	8231.6	6138.3	0.162	0.544	1.650
18.0	21141.4	15765.1	9705.6	7237.4	0.171	0.576	1.629
19.0	24512.3	18278.8	11342.3	8457.9	0.181	0.608	1.595
20.0	28185.9	21018.2	13149.6	9805.7	0.190	0.640	1.562
21.0	32318.9	24100.2	15135.7	11286.7	0.200	0.672	1.542
22.0	37138.0	27693.8	17308.3	12906.8	0.209	0.704	1.547
23.0	42602.6	31768.8	19675.3	14671.9	0.219	0.736	1.566
24.0	48252.7	35982.0	22244.6	16587.8	0.228	0.768	1.563
25.0	53536.5	39922.1	25024.1	18660.5	0.238	0.800	1.516
26.0	58595.8	43694.8	28021.4	20895.5	0.247	0.832	1.445
27.0	64009.8	47732.1	31244.3	23298.9	0.257	0.864	1.383
28.0	70591.8	52640.3	34700.5	25876.2	0.267	0.896	1.359
29.0	78410.9	58471.0	38397.8	28633.2	0.276	0.928	1.363
30.0	86964.6	64849.5	42343.7	31575.7	0.286	0.960	1.373
31.0	96130.4	71684.4	46545.8	34709.2	0.295	0.992	1.383
32.0	105839.7	78924.6	51011.9	38039.6	0.305	1.024	1.390
33.0	115989.0	86492.9	55749.4	41572.3	0.314	1.056	1.393
34.0	126434.0	94281.8	60765.9	45313.1	0.324	1.088	1.388
35.0	137088.4	102226.8	66069.0	49267.6	0.333	1.120	1.376
36.0	149203.8	111261.3	71666.1	53441.4	0.343	1.152	1.381
37.0	163359.5	121817.2	77564.7	57840.0	0.352	1.184	1.407
38.0	179738.8	134031.2	83772.3	62469.0	0.362	1.216	1.453
39.0	198505.4	148025.4	90296.3	67333.9	0.371	1.248	1.516
40.0	219797.9	163903.2	97144.1	72440.4	0.381	1.280	1.592
41.0	243723.4	181744.5	104323.2	77793.8	0.390	1.312	1.681
42.0	270351.2	201600.9	111841.0	83399.8	0.400	1.344	1.778
43.0	299705.9	223490.7	119704.7	89263.8	0.409	1.376	1.881
44.0	331760.0	247393.4	127921.8	95391.3	0.419	1.408	1.988
45.0	366426.4	273244.1	136499.6	101787.7	0.428	1.440	2.097

Table A.10 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position

Experiment Name JHSS Trimaran Outbd Aft (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	16133.3	12030.6	6912.2	5154.4	0.152	0.512	1.871
17.0	18963.0	14140.7	8231.6	6138.3	0.162	0.544	1.815
18.0	22023.2	16422.7	9705.6	7237.4	0.171	0.576	1.755
19.0	25416.3	18952.9	11342.3	8457.9	0.181	0.608	1.705
20.0	29257.9	21817.6	13149.6	9805.7	0.190	0.640	1.673
21.0	33430.9	24929.4	15135.7	11286.7	0.200	0.672	1.642
22.0	37821.3	28203.3	17308.3	12906.8	0.209	0.704	1.601
23.0	42490.4	31685.1	19675.3	14671.9	0.219	0.736	1.558
24.0	47547.4	35456.1	22244.6	16587.8	0.228	0.768	1.521
25.0	53153.2	39636.4	25024.1	18660.5	0.238	0.800	1.496
26.0	59406.5	44299.4	28021.4	20895.5	0.247	0.832	1.484
27.0	66317.1	49452.6	31244.3	23298.9	0.257	0.864	1.481
28.0	73863.8	55080.2	34700.5	25876.2	0.267	0.896	1.482
29.0	81988.7	61138.9	38397.8	28633.2	0.276	0.928	1.485
30.0	90589.5	67552.6	42343.7	31575.7	0.286	0.960	1.485
31.0	99513.8	74207.5	46545.8	34709.2	0.295	0.992	1.477
32.0	108682.4	81044.5	51011.9	38039.6	0.305	1.024	1.462
33.0	118204.0	88144.7	55749.4	41572.3	0.314	1.056	1.444
34.0	128261.7	95644.7	60765.9	45313.1	0.324	1.088	1.427
35.0	139111.9	103735.7	66069.0	49267.6	0.333	1.120	1.416
36.0	151095.6	112671.9	71666.1	53441.4	0.343	1.152	1.415
37.0	164650.2	122779.6	77564.7	57840.0	0.352	1.184	1.429
38.0	180322.5	134466.4	83772.3	62469.0	0.362	1.216	1.462
39.0	198780.5	148230.6	90296.3	67333.9	0.371	1.248	1.520
40.0	220556.4	164468.9	97144.1	72440.4	0.381	1.280	1.602
41.0	245604.3	183147.1	104323.2	77793.8	0.390	1.312	1.703
42.0	273664.4	204071.5	111841.0	83399.8	0.400	1.344	1.815
43.0	304309.5	226923.6	119704.7	89263.8	0.409	1.376	1.929
44.0	336922.2	251242.8	127921.8	95391.3	0.419	1.408	2.039
45.0	370671.0	276409.3	136499.6	101787.7	0.428	1.440	2.135

Table A.11 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 1 degree inboard

Experiment Name JHSS Trimaran 1 Deg Inbd (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	15397.6	11482.0	6912.2	5154.4	0.152	0.512	1.721
17.0	18385.9	13710.4	8231.6	6138.3	0.162	0.544	1.717
18.0	21609.5	16114.2	9705.6	7237.4	0.171	0.576	1.696
19.0	24945.0	18601.5	11342.3	8457.9	0.181	0.608	1.648
20.0	28606.4	21331.8	13149.6	9805.7	0.190	0.640	1.605
21.0	32989.4	24600.2	15135.7	11286.7	0.200	0.672	1.602
22.0	37915.8	28273.8	17308.3	12906.8	0.209	0.704	1.608
23.0	42869.8	31968.0	19675.3	14671.9	0.219	0.736	1.584
24.0	47873.1	35699.0	22244.6	16587.8	0.228	0.768	1.540
25.0	53247.7	39706.8	25024.1	18660.5	0.238	0.800	1.501
26.0	59103.8	44073.7	28021.4	20895.5	0.247	0.832	1.469
27.0	65488.3	48834.6	31244.3	23298.9	0.257	0.864	1.446
28.0	72673.0	54192.3	34700.5	25876.2	0.267	0.896	1.437
29.0	80985.0	60390.5	38397.8	28633.2	0.276	0.928	1.451
30.0	90074.9	67168.8	42343.7	31575.7	0.286	0.960	1.469
31.0	99251.1	74011.5	46545.8	34709.2	0.295	0.992	1.470
32.0	108388.3	80825.1	51011.9	38039.6	0.305	1.024	1.455
33.0	117695.9	87765.8	55749.4	41572.3	0.314	1.056	1.432
34.0	127672.5	95205.4	60765.9	45313.1	0.324	1.088	1.414
35.0	138910.5	103585.6	66069.0	49267.6	0.333	1.120	1.412
36.0	151389.3	112891.0	71666.1	53441.4	0.343	1.152	1.420
37.0	165054.9	123081.4	77564.7	57840.0	0.352	1.184	1.435
38.0	181292.6	135189.8	83772.3	62469.0	0.362	1.216	1.477
39.0	201936.8	150584.3	90296.3	67333.9	0.371	1.248	1.564
40.0	225520.4	168170.6	97144.1	72440.4	0.381	1.280	1.667
41.0	251454.8	187509.8	104323.2	77793.8	0.390	1.312	1.774
42.0	280002.4	208797.7	111841.0	83399.8	0.400	1.344	1.886
43.0	310651.4	231652.7	119704.7	89263.8	0.409	1.376	1.996
44.0	342833.6	255651.0	127921.8	95391.3	0.419	1.408	2.096
45.0	376133.0	280482.3	136499.6	101787.7	0.428	1.440	2.185

Table A.12 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 2.5 degrees inboard

Experiment Name JHSS Trimaran 2.5 Deg Inbd (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	15932.2	11880.6	6912.2	5154.4	0.152	0.512	1.830
17.0	18633.8	13895.2	8231.6	6138.3	0.162	0.544	1.759
18.0	21649.0	16143.7	9705.6	7237.4	0.171	0.576	1.702
19.0	25166.7	18766.8	11342.3	8457.9	0.181	0.608	1.675
20.0	29154.5	21740.5	13149.6	9805.7	0.190	0.640	1.662
21.0	33449.9	24943.6	15135.7	11286.7	0.200	0.672	1.643
22.0	38009.8	28343.9	17308.3	12906.8	0.209	0.704	1.615
23.0	42856.7	31958.2	19675.3	14671.9	0.219	0.736	1.583
24.0	48035.8	35820.3	22244.6	16587.8	0.228	0.768	1.550
25.0	53613.2	39979.3	25024.1	18660.5	0.238	0.800	1.520
26.0	59642.2	44475.2	28021.4	20895.5	0.247	0.832	1.495
27.0	66178.9	49349.6	31244.3	23298.9	0.257	0.864	1.475
28.0	73293.1	54654.6	34700.5	25876.2	0.267	0.896	1.461
29.0	81057.8	60444.8	38397.8	28633.2	0.276	0.928	1.453
30.0	89486.6	66730.2	42343.7	31575.7	0.286	0.960	1.451
31.0	98550.0	73488.7	46545.8	34709.2	0.295	0.992	1.451
32.0	108188.2	80675.9	51011.9	38039.6	0.305	1.024	1.450
33.0	118310.2	88223.9	55749.4	41572.3	0.314	1.056	1.447
34.0	128810.0	96053.6	60765.9	45313.1	0.324	1.088	1.439
35.0	139678.7	104158.4	66069.0	49267.6	0.333	1.120	1.427
36.0	151682.1	113109.3	71666.1	53441.4	0.343	1.152	1.425
37.0	165989.5	123778.3	77564.7	57840.0	0.352	1.184	1.451
38.0	183207.3	136617.7	83772.3	62469.0	0.362	1.216	1.506
39.0	203717.9	151912.4	90296.3	67333.9	0.371	1.248	1.589
40.0	227693.5	169791.0	97144.1	72440.4	0.381	1.280	1.695
41.0	254258.1	189600.2	104323.2	77793.8	0.390	1.312	1.808
42.0	283155.8	211149.2	111841.0	83399.8	0.400	1.344	1.921
43.0	314431.2	234471.3	119704.7	89263.8	0.409	1.376	2.035
44.0	347758.4	259323.4	127921.8	95391.3	0.419	1.408	2.144
45.0	382745.9	285413.6	136499.6	101787.7	0.428	1.440	2.245

Table A.13 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 5 degrees inboard

Experiment Name JHSS Trimaran 5 Deg Inbd (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	16317.5	12167.9	6912.2	5154.4	0.152	0.512	1.908
17.0	19559.6	14585.6	8231.6	6138.3	0.162	0.544	1.916
18.0	23189.7	17292.5	9705.6	7237.4	0.171	0.576	1.921
19.0	27187.1	20273.4	11342.3	8457.9	0.181	0.608	1.920
20.0	31509.2	23496.4	13149.6	9805.7	0.190	0.640	1.907
21.0	36098.6	26918.8	15135.7	11286.7	0.200	0.672	1.881
22.0	40938.5	30527.9	17308.3	12906.8	0.209	0.704	1.844
23.0	46037.7	34330.3	19675.3	14671.9	0.219	0.736	1.800
24.0	51425.4	38347.9	22244.6	16587.8	0.228	0.768	1.754
25.0	57159.1	42623.5	25024.1	18660.5	0.238	0.800	1.709
26.0	63338.0	47231.1	28021.4	20895.5	0.247	0.832	1.670
27.0	70109.4	52280.6	31244.3	23298.9	0.257	0.864	1.641
28.0	77675.9	57922.9	34700.5	25876.2	0.267	0.896	1.627
29.0	86250.4	64316.9	38397.8	28633.2	0.276	0.928	1.630
30.0	95730.4	71386.2	42343.7	31575.7	0.286	0.960	1.643
31.0	105774.0	78875.7	46545.8	34709.2	0.295	0.992	1.652
32.0	115869.0	86403.5	51011.9	38039.6	0.305	1.024	1.645
33.0	125488.5	93576.8	55749.4	41572.3	0.314	1.056	1.613
34.0	134975.1	100650.9	60765.9	45313.1	0.324	1.088	1.569
35.0	145222.8	108292.7	66069.0	49267.6	0.333	1.120	1.534
36.0	157476.9	117430.5	71666.1	53441.4	0.343	1.152	1.528
37.0	173106.7	129085.6	77564.7	57840.0	0.352	1.184	1.567
38.0	192140.4	143279.1	83772.3	62469.0	0.362	1.216	1.641
39.0	213815.8	159442.4	90296.3	67333.9	0.371	1.248	1.730
40.0	237505.0	177107.4	97144.1	72440.4	0.381	1.280	1.822
41.0	264195.0	197010.2	104323.2	77793.8	0.390	1.312	1.927
42.0	294414.3	219544.7	111841.0	83399.8	0.400	1.344	2.048
43.0	328236.9	244766.2	119704.7	89263.8	0.409	1.376	2.179
44.0	365670.1	272680.2	127921.8	95391.3	0.419	1.408	2.319
45.0	406645.8	303235.7	136499.6	101787.7	0.428	1.440	2.463

Table A.14 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 1 degree outboard

Experiment Name	JHSS Trimaran 1 Deg Outbd (PE from CR Input)			
	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	15724.6	11725.9	6912.2	5154.4	0.152	0.512	1.788
17.0	18123.4	13514.6	8231.6	6138.3	0.162	0.544	1.673
18.0	21209.1	15815.6	9705.6	7237.4	0.171	0.576	1.639
19.0	24799.6	18493.0	11342.3	8457.9	0.181	0.608	1.630
20.0	28547.6	21287.9	13149.6	9805.7	0.190	0.640	1.599
21.0	32759.1	24428.5	15135.7	11286.7	0.200	0.672	1.581
22.0	37616.7	28050.8	17308.3	12906.8	0.209	0.704	1.585
23.0	42883.5	31978.2	19675.3	14671.9	0.219	0.736	1.585
24.0	48141.6	35899.2	22244.6	16587.8	0.228	0.768	1.557
25.0	52969.3	39499.2	25024.1	18660.5	0.238	0.800	1.486
26.0	58015.1	43261.9	28021.4	20895.5	0.247	0.832	1.418
27.0	64399.3	48022.5	31244.3	23298.9	0.257	0.864	1.400
28.0	71965.3	53664.5	34700.5	25876.2	0.267	0.896	1.411
29.0	80077.1	59713.5	38397.8	28633.2	0.276	0.928	1.420
30.0	88641.7	66100.1	42343.7	31575.7	0.286	0.960	1.425
31.0	97664.0	72828.0	46545.8	34709.2	0.295	0.992	1.426
32.0	107152.7	79903.8	51011.9	38039.6	0.305	1.024	1.424
33.0	117096.0	87318.5	55749.4	41572.3	0.314	1.056	1.418
34.0	127517.5	95089.8	60765.9	45313.1	0.324	1.088	1.411
35.0	138536.6	103306.8	66069.0	49267.6	0.333	1.120	1.404
36.0	150316.5	112091.0	71666.1	53441.4	0.343	1.152	1.401
37.0	163370.1	121825.0	77564.7	57840.0	0.352	1.184	1.408
38.0	179559.0	133897.1	83772.3	62469.0	0.362	1.216	1.451
39.0	198659.2	148140.1	90296.3	67333.9	0.371	1.248	1.518
40.0	220329.0	164299.3	97144.1	72440.4	0.381	1.280	1.599
41.0	244518.4	182337.3	104323.2	77793.8	0.390	1.312	1.690
42.0	271094.5	202155.1	111841.0	83399.8	0.400	1.344	1.786
43.0	300954.1	224421.5	119704.7	89263.8	0.409	1.376	1.894
44.0	334177.2	249195.9	127921.8	95391.3	0.419	1.408	2.012
45.0	370407.7	276213.0	136499.6	101787.7	0.428	1.440	2.133

Table A.15 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 2.5 degrees outboard

Experiment Name JHSS Trimaran 2.5 Deg Out (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	16198.8	12079.4	6912.2	5154.4	0.152	0.512	1.884
17.0	18159.9	13541.9	8231.6	6138.3	0.162	0.544	1.679
18.0	20824.6	15528.9	9705.6	7237.4	0.171	0.576	1.584
19.0	24484.0	18257.7	11342.3	8457.9	0.181	0.608	1.592
20.0	28801.4	21477.2	13149.6	9805.7	0.190	0.640	1.626
21.0	33261.8	24803.3	15135.7	11286.7	0.200	0.672	1.626
22.0	37774.9	28168.8	17308.3	12906.8	0.209	0.704	1.597
23.0	42432.7	31642.1	19675.3	14671.9	0.219	0.736	1.554
24.0	47425.6	35365.3	22244.6	16587.8	0.228	0.768	1.514
25.0	53048.2	39558.0	25024.1	18660.5	0.238	0.800	1.490
26.0	59349.2	44256.7	28021.4	20895.5	0.247	0.832	1.481
27.0	66177.6	49348.6	31244.3	23298.9	0.257	0.864	1.475
28.0	73574.6	54864.6	34700.5	25876.2	0.267	0.896	1.471
29.0	81627.9	60869.9	38397.8	28633.2	0.276	0.928	1.473
30.0	90317.7	67349.9	42343.7	31575.7	0.286	0.960	1.476
31.0	99601.1	74272.5	46545.8	34709.2	0.295	0.992	1.480
32.0	109404.6	81583.0	51011.9	38039.6	0.305	1.024	1.481
33.0	119617.1	89198.5	55749.4	41572.3	0.314	1.056	1.477
34.0	130233.9	97115.4	60765.9	45313.1	0.324	1.088	1.469
35.0	141369.8	105419.5	66069.0	49267.6	0.333	1.120	1.459
36.0	153188.0	114232.3	71666.1	53441.4	0.343	1.152	1.452
37.0	165999.8	123786.0	77564.7	57840.0	0.352	1.184	1.451
38.0	180697.4	134746.0	83772.3	62469.0	0.362	1.216	1.468
39.0	198593.1	148090.8	90296.3	67333.9	0.371	1.248	1.517
40.0	220706.5	164580.8	97144.1	72440.4	0.381	1.280	1.604
41.0	245792.6	183287.5	104323.2	77793.8	0.390	1.312	1.706
42.0	273617.7	204036.7	111841.0	83399.8	0.400	1.344	1.814
43.0	304264.3	226889.8	119704.7	89263.8	0.409	1.376	1.929
44.0	337777.7	251880.8	127921.8	95391.3	0.419	1.408	2.047
45.0	374163.7	279013.9	136499.6	101787.7	0.428	1.440	2.167

Table A.16 – Effective power for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 5 degrees outboard

Experiment Name JHSS Trimaran 5 Deg Outbd (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	976.4	ft	20.54	ft
S	138322.8	ft^2	61.23	ft^2
Δ	40135.8	LT	813.90	lb
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16.0	17206.9	12831.2	6912.2	5154.4	0.152	0.512	2.088
17.0	19359.1	14436.1	8231.6	6138.3	0.162	0.544	1.882
18.0	22570.7	16831.0	9705.6	7237.4	0.171	0.576	1.833
19.0	26093.2	19457.7	11342.3	8457.9	0.181	0.608	1.787
20.0	30177.4	22503.3	13149.6	9805.7	0.190	0.640	1.769
21.0	34644.0	25834.0	15135.7	11286.7	0.200	0.672	1.750
22.0	39384.8	29369.3	17308.3	12906.8	0.209	0.704	1.723
23.0	44413.0	33118.8	19675.3	14671.9	0.219	0.736	1.689
24.0	49760.7	37106.5	22244.6	16587.8	0.228	0.768	1.654
25.0	55484.0	41374.4	25024.1	18660.5	0.238	0.800	1.620
26.0	61669.6	45987.0	28021.4	20895.5	0.247	0.832	1.591
27.0	68485.2	51069.4	31244.3	23298.9	0.257	0.864	1.572
28.0	76507.0	57051.2	34700.5	25876.2	0.267	0.896	1.582
29.0	85783.8	63969.0	38397.8	28633.2	0.276	0.928	1.614
30.0	95903.4	71515.2	42343.7	31575.7	0.286	0.960	1.648
31.0	106264.6	79241.5	46545.8	34709.2	0.295	0.992	1.666
32.0	116553.2	86913.7	51011.9	38039.6	0.305	1.024	1.662
33.0	126717.7	94493.3	55749.4	41572.3	0.314	1.056	1.641
34.0	136841.3	102042.5	60765.9	45313.1	0.324	1.088	1.608
35.0	147265.9	109816.2	66069.0	49267.6	0.333	1.120	1.574
36.0	158505.8	118197.7	71666.1	53441.4	0.343	1.152	1.547
37.0	171258.8	127707.7	77564.7	57840.0	0.352	1.184	1.537
38.0	186432.3	139022.6	83772.3	62469.0	0.362	1.216	1.555
39.0	205170.7	152995.8	90296.3	67333.9	0.371	1.248	1.609
40.0	228662.0	170513.3	97144.1	72440.4	0.381	1.280	1.708
41.0	256795.3	191492.2	104323.2	77793.8	0.390	1.312	1.838
42.0	288607.1	215214.3	111841.0	83399.8	0.400	1.344	1.983
43.0	322704.5	240640.7	119704.7	89263.8	0.409	1.376	2.122
44.0	357210.3	266371.7	127921.8	95391.3	0.419	1.408	2.237
45.0	389704.6	290602.7	136499.6	101787.7	0.428	1.440	2.309

Table A.17 – Model scale drag uncertainty analysis for a representative trimaran test condition

Spot Index	Test Spot Number	Model Speed (kts)	Model Speed (ft/s)	Model Total Resistance (lbf)
1	209	5.662	9.556	23.124
2	211	5.664	9.559	22.951
3	212	5.664	9.560	22.894
4	210	5.664	9.560	23.002
5	213	5.665	9.561	22.848
6	217	5.665	9.562	23.134
7	220	5.665	9.562	22.886
8	214	5.665	9.562	22.872
9	222	5.666	9.562	22.892
10	223	5.666	9.562	22.891
11	224	5.666	9.563	22.860
12	219	5.666	9.563	22.961
13	234	5.666	9.563	22.842
14	221	5.666	9.563	22.874
15	216	5.666	9.563	22.940
16	215	5.666	9.563	22.856
17	231	5.666	9.564	22.793
18	229	5.667	9.564	22.878
19	233	5.667	9.564	22.879
20	232	5.667	9.564	22.838
21	230	5.667	9.565	22.835
22	228	5.667	9.565	22.961
23	218	5.667	9.566	23.046
N=	23	Mean	9.5625	22.9157
N-1=	22	StdDev	0.0021	0.0891
t95(22)=	2.0739	Precision Limit	0.0044	0.1848
		Px/Mean=+/-U %	0.05%	0.81%
		Bias Limit	0.0017	0.0568
		Total Uncertainty	0.0047	0.1933
		UT/Mean %	**0.05%**	**0.84%**

TableA.18 – Model scale drag uncertainty analysis for a representative catamaran test condition

Spot Index	Test Spot Number	Model Speed (kts)	Model Speed (ft/s)	Model Total Resistance (lbf)
1	1074	5.665	9.561	4.852121
2	1072	5.665	9.562	4.888289
3	1068	5.665	9.562	4.912136
4	1069	5.665	9.562	4.904293
5	1071	5.665	9.562	4.915853
6	1067	5.665	9.562	4.854513
7	1073	5.666	9.562	4.853646
8	1070	5.666	9.563	4.921273
9	1060	5.669	9.569	4.85141
10	1062	5.670	9.570	4.902071
11	1061	5.670	9.570	4.868049
12	1063	5.670	9.570	4.8617
13	1065	5.670	9.571	4.873951
14	1064	5.671	9.571	4.853411
15	1066	5.671	9.571	4.824048
N=	15	Mean	9.5659	4.8758
N-1=	14	StdDev	0.0044	0.0295
t95(14)=	2.1448	Precision Limit	0.0094	0.0633
		Px/Mean=+/-U %	0.10%	1.30%
		Bias Limit	0.0017	0.0568
		Total Uncertainty	0.0095	0.0850
		UT/Mean %	**0.10%**	**1.74%**

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Appendix B – Sinkage and Trim

Table B.1 – Measured sinkage and trim for the fully appended center hull free to sink and trim

Ship Speed (kts)	1000*CR	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.343	0.09	0.02	-0.03	0.51	-0.04
17	1.307	0.10	0.02	-0.04	0.54	-0.07
18	1.279	0.11	0.02	-0.04	0.62	-0.11
19	1.269	0.13	0.02	-0.05	0.72	-0.15
20	1.264	0.15	0.02	-0.06	0.86	-0.19
21	1.252	0.18	0.02	-0.07	1.00	-0.22
22	1.224	0.20	0.03	-0.08	1.14	-0.25
23	1.181	0.22	0.03	-0.09	1.27	-0.25
24	1.153	0.25	0.04	-0.10	1.39	-0.26
25	1.163	0.27	0.05	-0.11	1.53	-0.26
26	1.179	0.30	0.05	-0.12	1.70	-0.29
27	1.160	0.34	0.06	-0.14	1.92	-0.35
28	1.127	0.38	0.06	-0.16	2.16	-0.43
29	1.109	0.43	0.05	-0.18	2.42	-0.53
30	1.102	0.47	0.05	-0.20	2.68	-0.64
31	1.096	0.51	0.04	-0.22	2.94	-0.75
32	1.088	0.55	0.04	-0.24	3.20	-0.84
33	1.081	0.60	0.05	-0.26	3.49	-0.90
34	1.087	0.66	0.06	-0.28	3.78	-0.93
35	1.121	0.71	0.08	-0.30	4.09	-0.94
36	1.197	0.77	0.10	-0.32	4.40	-0.92
37	1.320	0.83	0.13	-0.33	4.67	-0.87
38	1.455	0.87	0.17	-0.34	4.84	-0.72
39	1.575	0.89	0.22	-0.32	4.87	-0.44
40	1.727	0.89	0.29	-0.29	4.73	-0.02
41	1.880	0.88	0.38	-0.24	4.46	0.51
42	2.031	0.85	0.47	-0.18	4.10	1.10
43	2.191	0.81	0.56	-0.12	3.72	1.70
44	2.329	0.78	0.64	-0.06	3.33	2.29
45	2.419	0.75	0.72	-0.01	3.00	2.80

Table B.2 – Measured sinkage and trim for Side Hulls in a free to sink and trim catamaran configuration at a narrow (S/LWL=0.19) transverse centerline spacing

Ship Speed (kts)	1000*CR	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.271	-0.14	-0.02	0.10	-0.64	0.19
17	1.261	-0.08	0.00	0.08	-0.39	0.23
18	1.294	-0.05	0.03	0.07	-0.27	0.30
19	1.354	-0.05	0.04	0.08	-0.27	0.38
20	1.421	-0.06	0.04	0.10	-0.34	0.45
21	1.500	-0.08	0.04	0.11	-0.42	0.49
22	1.546	-0.09	0.04	0.12	-0.47	0.50
23	1.466	-0.09	0.03	0.11	-0.44	0.45
24	1.344	-0.07	0.03	0.09	-0.36	0.37
25	1.360	-0.06	0.03	0.08	-0.29	0.36
26	1.489	-0.06	0.05	0.10	-0.33	0.48
27	1.455	-0.09	0.08	0.16	-0.51	0.78
28	1.556	-0.15	0.13	0.26	-0.82	1.22
29	1.699	-0.22	0.18	0.37	-1.20	1.72
30	1.871	-0.30	0.23	0.49	-1.61	2.24
31	1.961	-0.39	0.27	0.60	-2.03	2.71
32	1.967	-0.46	0.30	0.70	-2.41	3.11
33	1.912	-0.52	0.32	0.77	-2.73	3.37
34	1.821	-0.58	0.32	0.82	-2.97	3.51
35	1.718	-0.61	0.31	0.85	-3.15	3.58
36	1.627	-0.64	0.30	0.87	-3.29	3.60
37	1.559	-0.67	0.29	0.88	-3.39	3.58
38	1.490	-0.69	0.28	0.89	-3.47	3.54
39	1.418	-0.71	0.26	0.89	-3.55	3.46
40	1.346	-0.73	0.23	0.88	-3.62	3.34
41	1.276	-0.74	0.21	0.87	-3.68	3.21
42	1.209	-0.75	0.18	0.86	-3.71	3.06
43	1.148	-0.76	0.15	0.84	-3.70	2.90
44	1.093	-0.75	0.13	0.81	-3.63	2.75
45	1.047	-0.72	0.12	0.77	-3.49	2.61

Table B.3 – Measured sinkage and trim for Side Hulls in a free to sink and trim catamaran configuration at a transverse centerline spacing equivalent to the inboard trimaran configuration

Ship Speed (kts)	1000*CR	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.178	-0.05	0.01	0.05	-0.24	0.17
17	1.267	-0.04	0.01	0.04	-0.19	0.16
18	1.332	-0.03	0.01	0.04	-0.16	0.16
19	1.373	-0.03	0.02	0.04	-0.15	0.18
20	1.391	-0.03	0.02	0.05	-0.17	0.22
21	1.386	-0.04	0.03	0.06	-0.21	0.28
22	1.358	-0.05	0.04	0.08	-0.26	0.36
23	1.316	-0.06	0.05	0.10	-0.34	0.46
24	1.283	-0.08	0.06	0.13	-0.43	0.58
25	1.285	-0.10	0.07	0.16	-0.53	0.72
26	1.338	-0.12	0.09	0.19	-0.65	0.87
27	1.420	-0.15	0.10	0.23	-0.78	1.03
28	1.497	-0.17	0.12	0.27	-0.91	1.20
29	1.535	-0.20	0.14	0.31	-1.04	1.38
30	1.528	-0.22	0.15	0.35	-1.18	1.55
31	1.495	-0.25	0.17	0.38	-1.31	1.72
32	1.454	-0.28	0.18	0.42	-1.45	1.88
33	1.417	-0.30	0.19	0.46	-1.58	2.02
34	1.385	-0.33	0.20	0.49	-1.70	2.14
35	1.356	-0.35	0.21	0.51	-1.82	2.24
36	1.320	-0.37	0.21	0.54	-1.94	2.32
37	1.283	-0.40	0.21	0.56	-2.05	2.37
38	1.263	-0.42	0.21	0.57	-2.15	2.39
39	1.209	-0.44	0.20	0.59	-2.25	2.40
40	1.168	-0.46	0.19	0.60	-2.34	2.39
41	1.134	-0.48	0.18	0.61	-2.43	2.37
42	1.094	-0.50	0.16	0.61	-2.51	2.34
43	1.055	-0.52	0.15	0.62	-2.59	2.30
44	1.014	-0.54	0.14	0.62	-2.67	2.27
45	0.977	-0.56	0.13	0.63	-2.74	2.23

Table B.4 – Measured sinkage and trim for Side Hulls in a free to sink and trim catamaran configuration at a transverse centerline spacing equivalent to the outboard trimaran configuration

Ship Speed (kts)	1000*CR	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.452	0.04	0.06	0.02	0.16	0.27
17	1.500	0.03	0.06	0.02	0.12	0.28
18	1.515	0.03	0.05	0.03	0.08	0.29
19	1.436	0.02	0.05	0.03	0.03	0.31
20	1.394	0.00	0.05	0.04	-0.02	0.33
21	1.403	-0.01	0.05	0.06	-0.09	0.36
22	1.412	-0.03	0.05	0.07	-0.16	0.41
23	1.420	-0.04	0.06	0.09	-0.25	0.47
24	1.401	-0.06	0.06	0.11	-0.34	0.55
25	1.387	-0.08	0.07	0.14	-0.45	0.66
26	1.409	-0.11	0.08	0.17	-0.57	0.80
27	1.455	-0.13	0.10	0.21	-0.70	0.96
28	1.503	-0.16	0.12	0.25	-0.84	1.15
29	1.534	-0.19	0.13	0.29	-0.99	1.34
30	1.540	-0.22	0.15	0.34	-1.14	1.53
31	1.526	-0.24	0.17	0.38	-1.28	1.70
32	1.496	-0.27	0.18	0.41	-1.43	1.84
33	1.457	-0.30	0.18	0.45	-1.57	1.96
34	1.412	-0.33	0.19	0.48	-1.70	2.06
35	1.368	-0.35	0.19	0.50	-1.82	2.13
36	1.329	-0.38	0.19	0.52	-1.94	2.20
37	1.296	-0.40	0.19	0.54	-2.04	2.25
38	1.267	-0.42	0.19	0.56	-2.14	2.29
39	1.239	-0.44	0.19	0.58	-2.23	2.33
40	1.197	-0.46	0.19	0.59	-2.30	2.36
41	1.166	-0.47	0.18	0.60	-2.37	2.38
42	1.128	-0.48	0.18	0.61	-2.43	2.40
43	1.088	-0.49	0.18	0.62	-2.48	2.42
44	1.049	-0.50	0.18	0.63	-2.53	2.43
45	1.031	-0.51	0.18	0.63	-2.57	2.44

Table B.5 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the inboard forward position

Ship Speed (kts)	CR*1000	Bow Trim + Sinkage (in)	Stern Trim + Sinkage (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.719	0.10	0.06	-0.02	0.47	0.16
17	1.637	0.11	0.05	-0.03	0.56	0.08
18	1.570	0.13	0.05	-0.04	0.68	0.01
19	1.523	0.16	0.05	-0.05	0.83	-0.03
20	1.496	0.19	0.05	-0.06	1.00	-0.05
21	1.490	0.22	0.06	-0.07	1.17	-0.06
22	1.502	0.25	0.08	-0.08	1.35	-0.05
23	1.533	0.29	0.09	-0.09	1.52	-0.04
24	1.572	0.32	0.10	-0.10	1.69	-0.03
25	1.601	0.35	0.11	-0.11	1.85	-0.04
26	1.602	0.37	0.11	-0.13	2.00	-0.10
27	1.566	0.40	0.10	-0.14	2.16	-0.21
28	1.511	0.43	0.08	-0.16	2.36	-0.35
29	1.453	0.47	0.07	-0.19	2.62	-0.48
30	1.410	0.52	0.07	-0.21	2.95	-0.59
31	1.386	0.59	0.08	-0.24	3.34	-0.68
32	1.388	0.66	0.10	-0.27	3.75	-0.75
33	1.420	0.74	0.11	-0.30	4.16	-0.80
34	1.479	0.81	0.13	-0.32	4.54	-0.83
35	1.562	0.88	0.16	-0.34	4.89	-0.79
36	1.666	0.94	0.20	-0.35	5.20	-0.67
37	1.791	1.00	0.26	-0.35	5.42	-0.45
38	1.944	1.04	0.33	-0.34	5.53	-0.11
39	2.130	1.05	0.41	-0.31	5.46	0.33
40	2.346	1.04	0.49	-0.26	5.20	0.87
41	2.576	1.00	0.59	-0.20	4.80	1.50
42	2.803	0.95	0.69	-0.13	4.30	2.20
43	3.009	0.89	0.79	-0.05	3.74	2.93
44	3.177	0.83	0.90	0.03	3.16	3.69
45	3.290	0.78	1.01	0.11	2.61	4.44

Table B.6 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard forward position

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.740	0.11	0.04	-0.03	0.58	0.04
17	1.640	0.13	0.04	-0.04	0.71	-0.02
18	1.580	0.15	0.04	-0.05	0.83	-0.04
19	1.554	0.18	0.05	-0.06	0.94	-0.04
20	1.546	0.20	0.06	-0.06	1.04	-0.03
21	1.542	0.22	0.07	-0.07	1.15	-0.03
22	1.526	0.24	0.07	-0.08	1.28	-0.04
23	1.502	0.26	0.07	-0.09	1.43	-0.10
24	1.477	0.29	0.07	-0.11	1.61	-0.18
25	1.462	0.32	0.06	-0.13	1.80	-0.27
26	1.464	0.36	0.06	-0.14	2.01	-0.33
27	1.476	0.40	0.07	-0.16	2.23	-0.36
28	1.481	0.44	0.08	-0.17	2.45	-0.37
29	1.461	0.48	0.09	-0.19	2.69	-0.40
30	1.410	0.53	0.10	-0.20	2.94	-0.46
31	1.357	0.58	0.10	-0.23	3.23	-0.55
32	1.330	0.63	0.10	-0.26	3.57	-0.68
33	1.338	0.70	0.09	-0.29	3.98	-0.83
34	1.383	0.77	0.10	-0.32	4.41	-0.95
35	1.471	0.85	0.12	-0.35	4.79	-0.98
36	1.604	0.91	0.16	-0.36	5.06	-0.84
37	1.783	0.95	0.23	-0.34	5.19	-0.53
38	1.974	0.97	0.31	-0.32	5.17	-0.09
39	2.166	0.98	0.40	-0.28	5.02	0.42
40	2.355	0.96	0.49	-0.23	4.75	0.98
41	2.538	0.93	0.57	-0.17	4.36	1.58
42	2.712	0.88	0.66	-0.10	3.90	2.20
43	2.874	0.82	0.75	-0.03	3.38	2.85
44	3.020	0.76	0.85	0.04	2.82	3.52
45	3.147	0.69	0.94	0.12	2.25	4.21

Table B.7 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the inboard aft position

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.643	0.09	0.05	-0.02	0.45	0.11
17	1.650	0.11	0.05	-0.03	0.53	0.08
18	1.629	0.12	0.05	-0.03	0.62	0.04
19	1.595	0.13	0.05	-0.04	0.70	0.02
20	1.562	0.15	0.05	-0.05	0.78	0.01
21	1.542	0.17	0.06	-0.05	0.87	0.01
22	1.547	0.18	0.07	-0.06	0.95	0.03
23	1.566	0.20	0.08	-0.06	1.04	0.06
24	1.563	0.22	0.09	-0.07	1.16	0.08
25	1.516	0.25	0.09	-0.08	1.32	0.05
26	1.445	0.29	0.09	-0.09	1.53	-0.04
27	1.383	0.33	0.08	-0.12	1.77	-0.15
28	1.359	0.36	0.08	-0.13	1.98	-0.22
29	1.363	0.39	0.10	-0.14	2.13	-0.20
30	1.373	0.41	0.12	-0.14	2.22	-0.10
31	1.383	0.43	0.15	-0.14	2.28	0.03
32	1.390	0.45	0.18	-0.13	2.34	0.17
33	1.393	0.48	0.21	-0.13	2.45	0.27
34	1.388	0.51	0.23	-0.14	2.60	0.34
35	1.376	0.56	0.25	-0.15	2.80	0.39
36	1.381	0.61	0.27	-0.16	3.06	0.42
37	1.407	0.66	0.30	-0.17	3.33	0.46
38	1.453	0.71	0.33	-0.18	3.55	0.55
39	1.516	0.74	0.37	-0.18	3.67	0.74
40	1.592	0.76	0.43	-0.16	3.68	1.03
41	1.681	0.77	0.49	-0.13	3.58	1.42
42	1.778	0.76	0.57	-0.09	3.40	1.88
43	1.881	0.75	0.65	-0.04	3.14	2.41
44	1.988	0.72	0.74	0.01	2.81	2.98
45	2.097	0.69	0.83	0.07	2.42	3.60

Table B.8 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.871	0.09	0.04	-0.02	0.44	0.08
17	1.815	0.10	0.05	-0.03	0.52	0.09
18	1.755	0.12	0.06	-0.03	0.58	0.12
19	1.705	0.13	0.07	-0.03	0.62	0.16
20	1.673	0.14	0.08	-0.03	0.67	0.19
21	1.642	0.15	0.08	-0.03	0.73	0.20
22	1.601	0.17	0.08	-0.04	0.83	0.15
23	1.558	0.19	0.07	-0.05	0.97	0.06
24	1.521	0.21	0.07	-0.07	1.13	-0.03
25	1.496	0.24	0.07	-0.08	1.31	-0.08
26	1.484	0.28	0.08	-0.09	1.49	-0.07
27	1.481	0.31	0.10	-0.10	1.66	-0.01
28	1.482	0.35	0.13	-0.10	1.80	0.07
29	1.485	0.37	0.15	-0.11	1.91	0.14
30	1.485	0.39	0.16	-0.11	1.99	0.20
31	1.477	0.41	0.17	-0.11	2.09	0.22
32	1.462	0.44	0.18	-0.12	2.24	0.22
33	1.444	0.48	0.19	-0.14	2.46	0.18
34	1.427	0.53	0.20	-0.16	2.73	0.14
35	1.416	0.58	0.21	-0.17	3.00	0.13
36	1.415	0.63	0.24	-0.19	3.26	0.17
37	1.429	0.67	0.27	-0.19	3.47	0.27
38	1.462	0.71	0.31	-0.19	3.61	0.45
39	1.520	0.74	0.36	-0.18	3.66	0.70
40	1.602	0.75	0.42	-0.16	3.62	1.04
41	1.703	0.75	0.49	-0.12	3.48	1.45
42	1.815	0.74	0.57	-0.08	3.24	1.93
43	1.929	0.71	0.65	-0.03	2.92	2.48
44	2.039	0.67	0.74	0.03	2.52	3.09
45	2.135	0.62	0.84	0.10	2.03	3.77

Table B.9 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 1 degree inboard

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.721	0.09	0.03	-0.03	0.45	-0.01
17	1.717	0.12	0.08	-0.02	0.57	0.23
18	1.696	0.14	0.10	-0.02	0.64	0.33
19	1.648	0.15	0.11	-0.02	0.69	0.34
20	1.605	0.15	0.10	-0.03	0.73	0.27
21	1.602	0.16	0.08	-0.04	0.78	0.16
22	1.608	0.17	0.06	-0.05	0.87	0.05
23	1.584	0.19	0.06	-0.06	1.01	-0.03
24	1.540	0.22	0.06	-0.08	1.20	-0.07
25	1.501	0.26	0.07	-0.09	1.40	-0.08
26	1.469	0.29	0.08	-0.10	1.55	-0.07
27	1.446	0.31	0.09	-0.10	1.63	-0.05
28	1.437	0.32	0.11	-0.10	1.69	0.00
29	1.451	0.34	0.13	-0.10	1.76	0.09
30	1.469	0.37	0.16	-0.10	1.87	0.21
31	1.470	0.40	0.19	-0.10	2.02	0.32
32	1.455	0.44	0.21	-0.11	2.22	0.37
33	1.432	0.49	0.21	-0.13	2.46	0.31
34	1.414	0.53	0.21	-0.15	2.74	0.18
35	1.412	0.58	0.21	-0.18	3.04	0.08
36	1.420	0.64	0.22	-0.20	3.34	0.06
37	1.435	0.70	0.26	-0.21	3.62	0.16
38	1.477	0.74	0.31	-0.21	3.81	0.37
39	1.564	0.77	0.37	-0.19	3.86	0.69
40	1.667	0.78	0.45	-0.16	3.76	1.10
41	1.774	0.77	0.52	-0.12	3.55	1.58
42	1.886	0.75	0.61	-0.07	3.25	2.13
43	1.996	0.72	0.70	-0.01	2.91	2.72
44	2.096	0.70	0.79	0.05	2.56	3.34
45	2.185	0.68	0.89	0.10	2.25	3.96

Table B.10 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 2.5 degrees inboard

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.830	0.11	0.04	-0.03	0.56	0.05
17	1.759	0.12	0.05	-0.03	0.60	0.04
18	1.702	0.12	0.05	-0.04	0.64	0.05
19	1.675	0.14	0.06	-0.04	0.70	0.07
20	1.662	0.15	0.07	-0.04	0.77	0.09
21	1.643	0.17	0.07	-0.05	0.85	0.11
22	1.615	0.19	0.08	-0.05	0.96	0.11
23	1.583	0.21	0.09	-0.06	1.10	0.10
24	1.550	0.24	0.09	-0.07	1.25	0.07
25	1.520	0.27	0.10	-0.08	1.40	0.04
26	1.495	0.29	0.10	-0.09	1.52	0.01
27	1.475	0.31	0.10	-0.10	1.62	-0.01
28	1.461	0.32	0.11	-0.10	1.71	-0.01
29	1.453	0.35	0.12	-0.11	1.82	0.04
30	1.451	0.38	0.15	-0.11	1.95	0.14
31	1.451	0.42	0.18	-0.11	2.13	0.23
32	1.450	0.46	0.20	-0.12	2.32	0.29
33	1.447	0.50	0.21	-0.14	2.55	0.27
34	1.439	0.54	0.21	-0.16	2.80	0.20
35	1.427	0.59	0.22	-0.18	3.08	0.14
36	1.425	0.65	0.24	-0.20	3.39	0.13
37	1.451	0.71	0.27	-0.21	3.70	0.21
38	1.506	0.77	0.32	-0.21	3.92	0.39
39	1.589	0.79	0.38	-0.20	3.97	0.68
40	1.695	0.80	0.45	-0.17	3.84	1.08
41	1.808	0.77	0.52	-0.12	3.57	1.57
42	1.921	0.74	0.61	-0.06	3.20	2.15
43	2.035	0.71	0.70	0.00	2.80	2.79
44	2.144	0.67	0.81	0.06	2.40	3.48
45	2.245	0.66	0.93	0.13	2.07	4.20

Table B.11 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 5 degrees outboard

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.908	0.09	0.06	-0.02	0.45	0.14
17	1.916	0.10	0.06	-0.02	0.49	0.17
18	1.921	0.11	0.07	-0.02	0.54	0.19
19	1.920	0.13	0.08	-0.02	0.59	0.20
20	1.907	0.14	0.08	-0.03	0.66	0.20
21	1.881	0.15	0.08	-0.03	0.74	0.19
22	1.844	0.17	0.08	-0.04	0.84	0.16
23	1.800	0.19	0.09	-0.05	0.96	0.13
24	1.754	0.21	0.09	-0.06	1.09	0.10
25	1.709	0.24	0.09	-0.07	1.25	0.06
26	1.670	0.27	0.10	-0.08	1.42	0.04
27	1.641	0.30	0.11	-0.09	1.59	0.05
28	1.627	0.34	0.13	-0.10	1.77	0.10
29	1.630	0.38	0.16	-0.10	1.93	0.21
30	1.643	0.42	0.20	-0.11	2.10	0.34
31	1.652	0.46	0.23	-0.11	2.26	0.45
32	1.645	0.50	0.25	-0.12	2.44	0.52
33	1.613	0.53	0.26	-0.13	2.64	0.51
34	1.569	0.57	0.26	-0.15	2.85	0.44
35	1.534	0.61	0.26	-0.16	3.09	0.37
36	1.528	0.66	0.27	-0.18	3.35	0.33
37	1.567	0.71	0.30	-0.20	3.63	0.37
38	1.641	0.76	0.34	-0.20	3.85	0.52
39	1.730	0.79	0.40	-0.19	3.91	0.80
40	1.822	0.79	0.47	-0.15	3.76	1.22
41	1.927	0.77	0.56	-0.10	3.48	1.77
42	2.048	0.75	0.65	-0.04	3.14	2.41
43	2.179	0.72	0.77	0.02	2.74	3.13
44	2.319	0.68	0.88	0.10	2.31	3.89
45	2.463	0.65	1.00	0.17	1.86	4.68

Table B.12 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 1 degree outboard

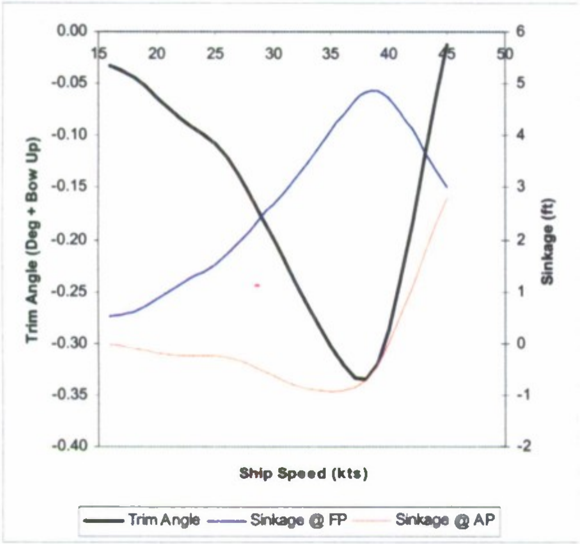
Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.788	0.10	0.06	-0.02	0.48	0.14
17	1.673	0.12	0.06	-0.03	0.61	0.10
18	1.639	0.14	0.05	-0.04	0.72	0.04
19	1.630	0.15	0.07	-0.04	0.74	0.11
20	1.599	0.15	0.09	-0.03	0.73	0.22
21	1.581	0.16	0.09	-0.03	0.76	0.23
22	1.585	0.17	0.08	-0.04	0.84	0.14
23	1.585	0.18	0.06	-0.06	0.96	0.00
24	1.557	0.20	0.05	-0.07	1.11	-0.11
25	1.486	0.23	0.05	-0.09	1.28	-0.16
26	1.418	0.27	0.07	-0.10	1.46	-0.13
27	1.400	0.31	0.09	-0.10	1.63	-0.05
28	1.411	0.34	0.12	-0.11	1.81	0.04
29	1.420	0.38	0.14	-0.11	1.97	0.10
30	1.425	0.41	0.16	-0.12	2.10	0.14
31	1.426	0.43	0.17	-0.12	2.22	0.15
32	1.424	0.46	0.18	-0.13	2.36	0.17
33	1.418	0.49	0.19	-0.14	2.53	0.19
34	1.411	0.53	0.21	-0.15	2.74	0.21
35	1.404	0.58	0.23	-0.17	2.97	0.23
36	1.401	0.63	0.25	-0.18	3.22	0.26
37	1.408	0.67	0.28	-0.19	3.46	0.30
38	1.451	0.72	0.31	-0.19	3.64	0.41
39	1.518	0.75	0.35	-0.19	3.73	0.62
40	1.599	0.76	0.41	-0.17	3.71	0.94
41	1.690	0.76	0.48	-0.13	3.58	1.35
42	1.786	0.75	0.56	-0.09	3.37	1.84
43	1.894	0.74	0.65	-0.04	3.09	2.39
44	2.012	0.71	0.74	0.02	2.74	2.99
45	2.133	0.67	0.83	0.08	2.33	3.63

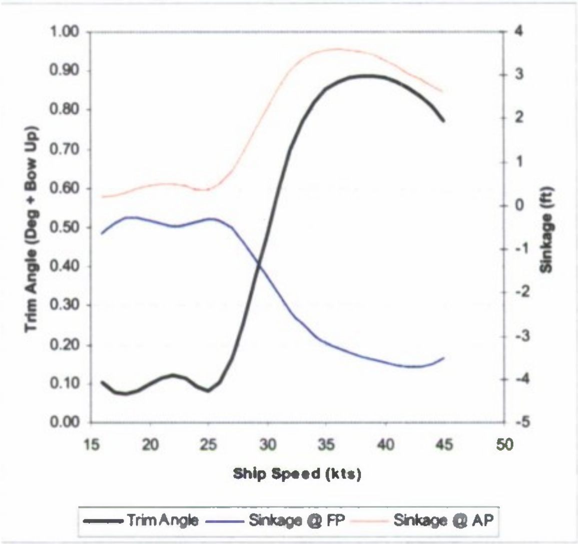
Table B.13 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 2.5 degrees outboard

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	1.884	0.06	0.03	-0.02	0.30	0.04
17	1.679	0.11	0.05	-0.03	0.53	0.10
18	1.584	0.14	0.07	-0.04	0.70	0.11
19	1.592	0.16	0.07	-0.04	0.80	0.10
20	1.626	0.16	0.07	-0.05	0.85	0.07
21	1.626	0.17	0.06	-0.05	0.88	0.02
22	1.597	0.18	0.06	-0.06	0.93	-0.02
23	1.554	0.19	0.06	-0.06	1.02	-0.05
24	1.514	0.22	0.06	-0.07	1.16	-0.06
25	1.490	0.26	0.07	-0.09	1.38	-0.09
26	1.481	0.29	0.08	-0.10	1.58	-0.09
27	1.475	0.31	0.10	-0.10	1.67	-0.05
28	1.471	0.32	0.11	-0.10	1.70	0.01
29	1.473	0.34	0.12	-0.10	1.77	0.07
30	1.476	0.37	0.14	-0.11	1.90	0.11
31	1.480	0.40	0.16	-0.12	2.07	0.15
32	1.481	0.45	0.18	-0.13	2.29	0.20
33	1.477	0.50	0.21	-0.14	2.54	0.25
34	1.469	0.55	0.23	-0.15	2.81	0.30
35	1.459	0.60	0.26	-0.17	3.08	0.34
36	1.452	0.65	0.28	-0.18	3.34	0.36
37	1.451	0.70	0.30	-0.19	3.55	0.38
38	1.468	0.73	0.32	-0.20	3.70	0.45
39	1.517	0.75	0.35	-0.19	3.74	0.62
40	1.604	0.75	0.40	-0.17	3.66	0.91
41	1.706	0.75	0.47	-0.13	3.51	1.30
42	1.814	0.73	0.54	-0.09	3.28	1.78
43	1.929	0.71	0.63	-0.04	2.99	2.33
44	2.047	0.69	0.72	0.02	2.67	2.94
45	2.167	0.67	0.82	0.08	2.32	3.58

Table B.14 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 5 degrees outboard

Ship Speed (kts)	CR*1000	Bow Trim (in)	Stern Trim (in)	Pitch Angle + Bow Up (Deg)	Bow Sinkage (ft)	Stern Sinkage (ft)
16	2.088	0.09	0.05	-0.02	0.46	0.08
17	1.882	0.13	0.06	-0.03	0.64	0.09
18	1.833	0.15	0.07	-0.04	0.73	0.11
19	1.787	0.15	0.07	-0.04	0.75	0.14
20	1.769	0.15	0.08	-0.03	0.74	0.17
21	1.750	0.15	0.08	-0.03	0.75	0.18
22	1.723	0.16	0.08	-0.04	0.81	0.17
23	1.689	0.18	0.08	-0.05	0.93	0.12
24	1.654	0.21	0.08	-0.06	1.12	0.04
25	1.620	0.26	0.08	-0.09	1.39	-0.06
26	1.591	0.30	0.08	-0.10	1.62	-0.10
27	1.572	0.33	0.11	-0.10	1.72	0.00
28	1.582	0.34	0.14	-0.10	1.74	0.16
29	1.614	0.35	0.16	-0.09	1.76	0.25
30	1.648	0.36	0.16	-0.09	1.80	0.27
31	1.666	0.37	0.17	-0.10	1.88	0.26
32	1.662	0.39	0.18	-0.10	1.99	0.27
33	1.641	0.43	0.20	-0.11	2.15	0.32
34	1.608	0.47	0.23	-0.12	2.35	0.41
35	1.574	0.52	0.26	-0.13	2.60	0.49
36	1.547	0.59	0.29	-0.14	2.92	0.55
37	1.537	0.66	0.31	-0.16	3.28	0.55
38	1.555	0.72	0.34	-0.18	3.59	0.57
39	1.609	0.76	0.37	-0.19	3.76	0.68
40	1.708	0.76	0.42	-0.17	3.71	0.96
41	1.838	0.76	0.48	-0.13	3.53	1.37
42	1.983	0.74	0.56	-0.08	3.27	1.87
43	2.122	0.71	0.65	-0.03	2.94	2.45
44	2.237	0.68	0.75	0.03	2.57	3.08
45	2.309	0.65	0.84	0.09	2.17	3.73

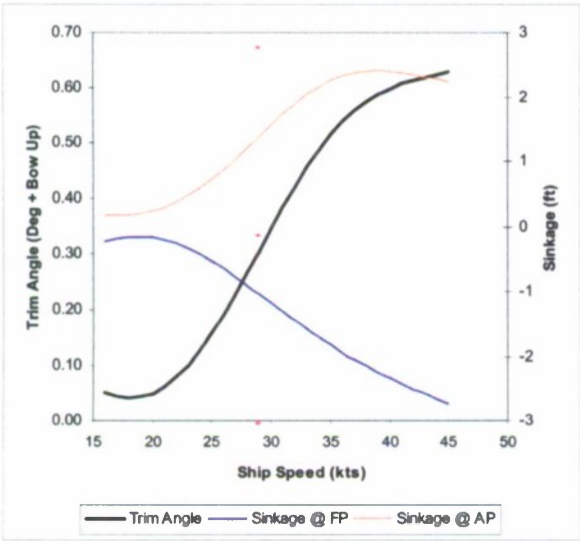


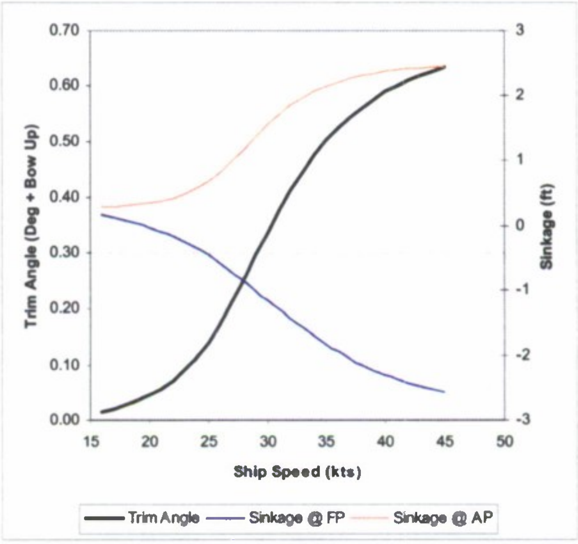


B.1 *B.2*

Figure B.1 – Measured sinkage and trim for the fully appended Center Hull in a free to sink and trim catamaran configuration

Figure B.2 – Measured sinkage and trim for Side Hulls in a free to sink and trim catamaran configuration at a narrow (S/LWL=0.19) transverse centerline spacing

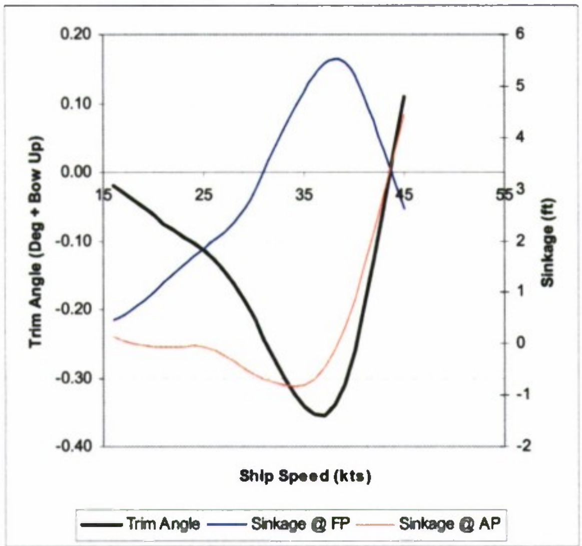


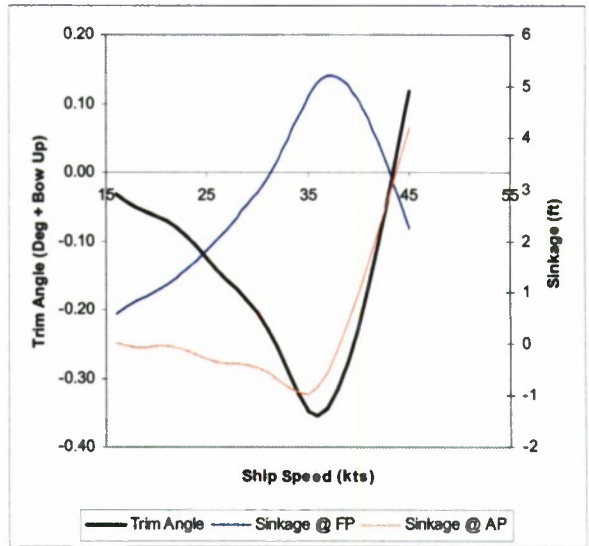


B.3 *B.4*

Figure B.3 – Measured sinkage and trim for Side Hulls in a free to sink and trim catamaran configuration at a transverse centerline spacing equivalent to the inboard trimaran configuration

Figure B.4 – Measured sinkage and trim for Side Hulls in a free to sink and trim catamaran configuration at a transverse centerline spacing equivalent to the outboard trimaran configuration

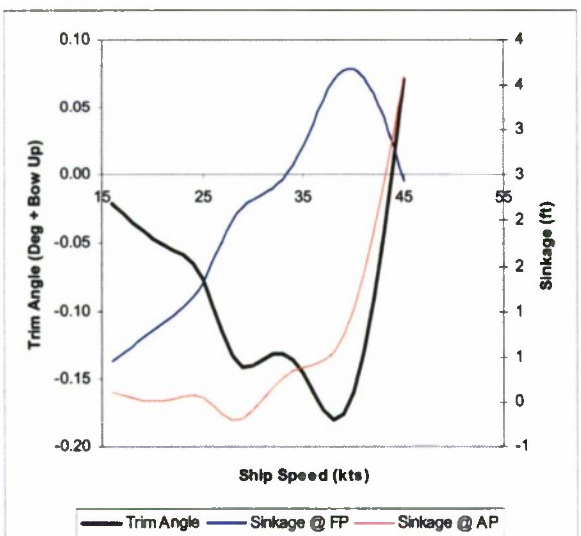


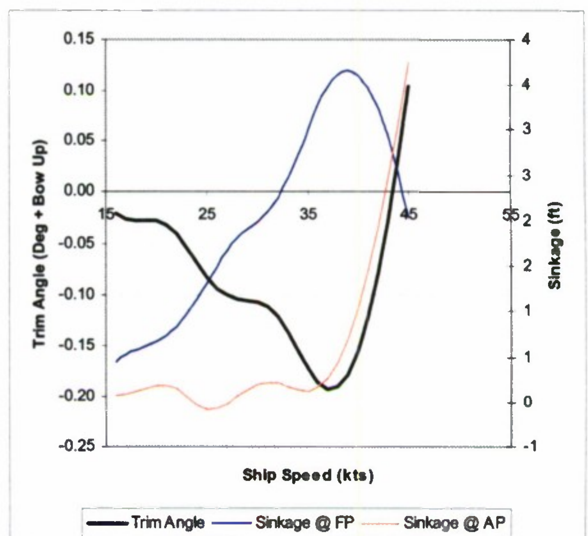


B.5 *B.6*

Figure B.5 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the inboard forward position

Figure B.6 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard forward position

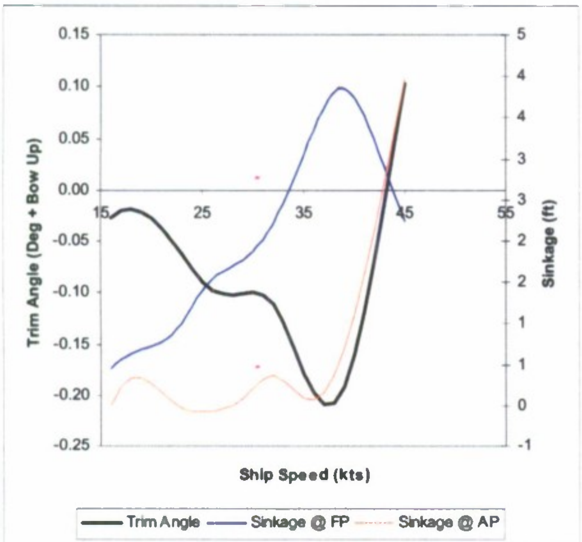


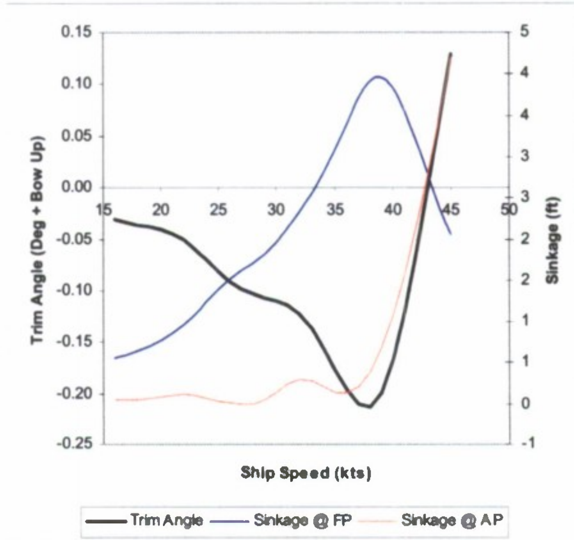


B.7 *B.8*

Figure B.7 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the inboard aft position

Figure B.8 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position

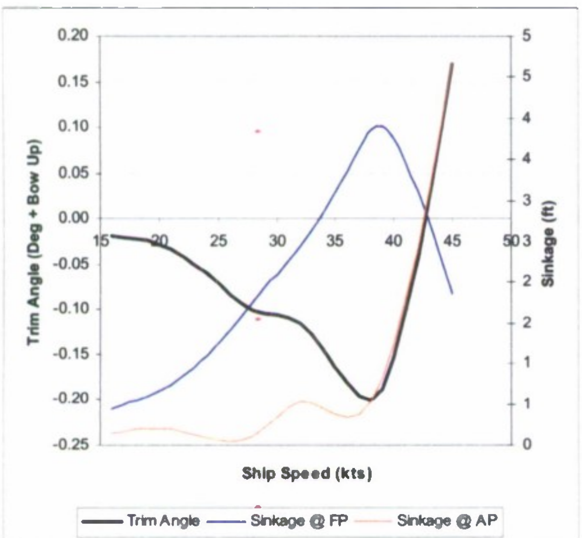




B.9 B.10

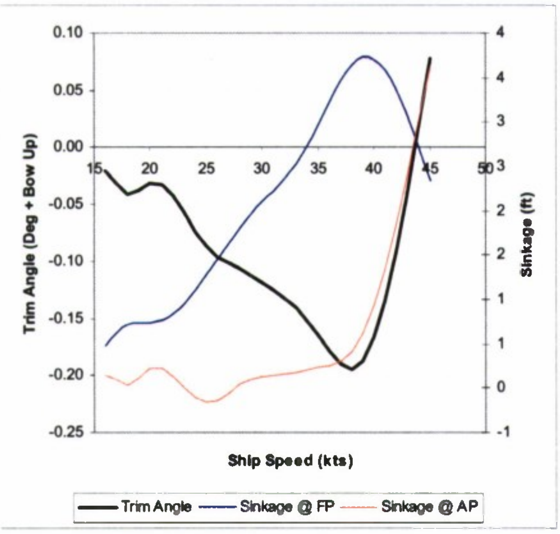
Figure B.9 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 1 degree inboard

Figure B.10 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 2.5 degrees inboard

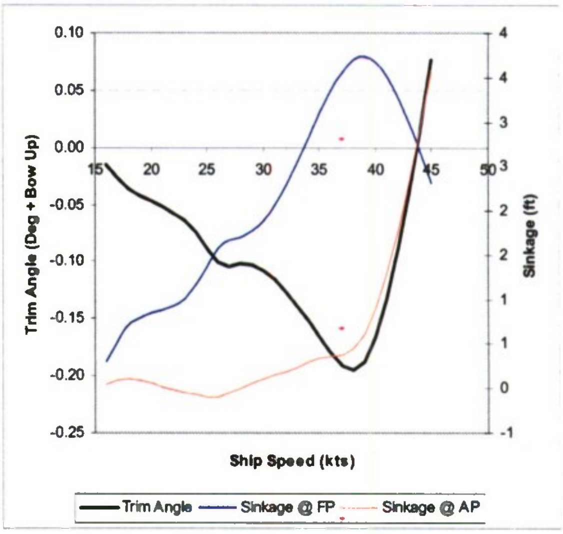


B.11

Figure B.11 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 5 degrees outboard



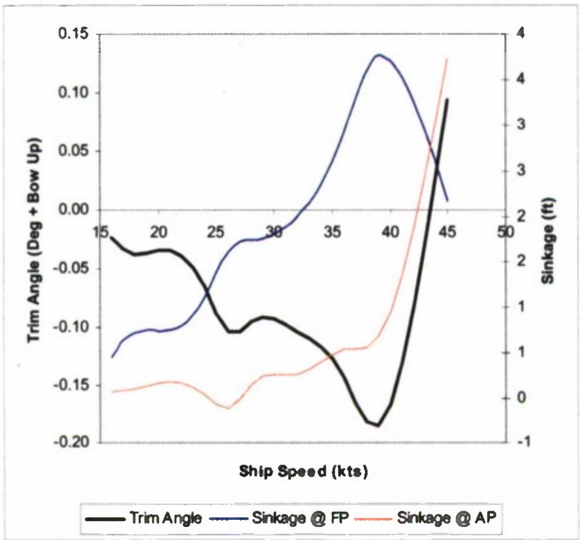
B.12



B.13

Figure B.12 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 1 degree outboard

Figure B.13 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 2.5 degrees outboard



B.14

Figure B.14 – Measured sinkage and trim for the fully appended trimaran free to sink and trim with the side hulls in the outboard aft position with a toe angle of 5 degrees outboard

Appendix C – Lift and Drag Forces on Side Hulls Measured During Trimaran Configuration Tests

Table C.1 – Model scale forces measured on the starboard side hull in the inboard forward trimaran condition

Ship Speed (kts)	Net Drag Force (lbf)	Net Side Force (lbf)	Angle (Deg + clockwise from dead aft)	Magnitude (lbf)	CR*1000	L/D Ratio
16	0.087	0.036	22.453	0.095	1.118	0.413
17	0.162	0.028	9.754	0.164	1.140	0.172
18	0.275	0.017	3.493	0.276	1.083	0.061
19	0.411	0.004	0.556	0.411	0.974	0.010
20	0.553	-0.010	-1.023	0.553	0.848	0.018
21	0.683	-0.024	-2.012	0.683	0.738	0.035
22	0.785	-0.038	-2.742	0.786	0.681	0.048
23	0.845	-0.050	-3.356	0.846	0.709	0.059
24	0.869	-0.050	-3.310	0.870	0.801	0.058
25	0.889	-0.023	-1.457	0.889	0.876	0.025
26	0.935	0.051	3.095	0.937	0.852	0.054
27	1.014	0.167	9.334	1.027	0.695	0.164
28	1.086	0.289	14.902	1.124	0.477	0.266
29	1.111	0.378	18.804	1.174	0.280	0.341
30	1.068	0.409	20.942	1.143	0.166	0.383
31	1.004	0.399	21.654	1.081	0.118	0.397
32	0.985	0.377	20.961	1.055	0.098	0.383
33	1.062	0.370	19.191	1.125	0.076	0.348
34	1.224	0.384	17.407	1.283	0.075	0.314
35	1.431	0.420	16.351	1.491	0.142	0.293
36	1.646	0.478	16.188	1.714	0.320	0.290
37	1.868	0.552	16.458	1.948	0.614	0.295
38	2.120	0.631	16.567	2.212	0.989	0.297
39	2.426	0.703	16.168	2.526	1.414	0.290
40	2.795	0.765	15.301	2.897	1.863	0.274
41	3.211	0.816	14.256	3.313	2.320	0.254
42	3.659	0.860	13.221	3.758	2.774	0.235
43	4.122	0.898	12.290	4.219	3.209	0.218
44	4.585	0.934	11.508	4.679	3.614	0.204
45	5.032	0.968	10.895	5.124	3.975	0.192

Table C.2 – Model scale forces measured on the starboard side hull in the inboard aft trimaran condition

Ship Speed	Net Drag Force	Net Side Force	Angle	Magnitude	CR*1000	L/D Ratio
(kts)	(lbf)	(lbf)	(Deg + clockwise from dead aft)	(lbf)		
16	0.407	-0.031	-4.314	0.408	0.738	0.075
17	0.460	-0.038	-4.683	0.461	0.781	0.082
18	0.509	-0.032	-3.645	0.510	0.821	0.064
19	0.557	-0.022	-2.219	0.558	0.862	0.039
20	0.609	-0.012	-1.118	0.609	0.893	0.020
21	0.668	-0.010	-0.857	0.669	0.910	0.015
22	0.739	-0.022	-1.739	0.739	0.904	0.030
23	0.815	-0.045	-3.188	0.816	0.859	0.056
24	0.878	-0.059	-3.827	0.880	0.732	0.067
25	0.908	-0.041	-2.575	0.909	0.503	0.045
26	0.894	0.022	1.401	0.894	0.205	0.024
27	0.862	0.108	7.172	0.869	-0.058	0.126
28	0.849	0.189	12.540	0.870	-0.192	0.222
29	0.891	0.235	14.771	0.921	-0.214	0.264
30	0.984	0.238	13.608	1.013	-0.155	0.242
31	1.105	0.206	10.562	1.124	-0.054	0.186
32	1.225	0.145	6.748	1.233	0.051	0.118
33	1.325	0.067	2.876	1.327	0.118	0.050
34	1.395	-0.010	-0.420	1.395	0.118	0.007
35	1.426	-0.066	-2.637	1.427	0.031	0.046
36	1.413	-0.084	-3.388	1.416	-0.130	0.059
37	1.370	-0.065	-2.728	1.371	-0.337	0.048
38	1.313	-0.017	-0.727	1.313	-0.557	0.013
39	1.261	0.056	2.546	1.262	-0.751	0.044
40	1.223	0.148	6.898	1.232	-0.911	0.121
41	1.206	0.255	11.950	1.232	-1.029	0.212
42	1.213	0.374	17.120	1.269	-1.098	0.308
43	1.250	0.499	21.777	1.346	-1.118	0.400
44	1.322	0.629	25.430	1.464	-1.104	0.475
45	1.434	0.757	27.842	1.622	-1.075	0.528

Table C.3 – Model scale forces measured on the starboard side hull in the outboard forward trimaran condition

Ship Speed (kts)	Net Drag Force (lbf)	Net Side Force (lbf)	Angle (Deg + clockwise from dead aft)	Magnitude	CR*1000	L/D Ratio
16	0.483	0.035	4.172	0.484	1.598	0.073
17	0.492	0.027	3.124	0.492	1.275	0.055
18	0.533	0.012	1.315	0.533	1.115	0.023
19	0.596	-0.005	-0.462	0.596	1.102	0.008
20	0.671	-0.021	-1.779	0.671	1.168	0.031
21	0.746	-0.032	-2.486	0.747	1.249	0.043
22	0.812	-0.036	-2.544	0.813	1.278	0.044
23	0.858	-0.029	-1.911	0.858	1.193	0.033
24	0.889	-0.011	-0.721	0.889	1.009	0.013
25	0.927	0.010	0.634	0.927	0.835	0.011
26	0.995	0.030	1.705	0.995	0.782	0.030
27	1.099	0.045	2.333	1.100	0.889	0.041
28	1.214	0.061	2.888	1.215	1.051	0.050
29	1.311	0.085	3.727	1.314	1.143	0.065
30	1.372	0.122	5.081	1.377	1.080	0.089
31	1.411	0.169	6.843	1.421	0.924	0.120
32	1.452	0.224	8.783	1.470	0.771	0.155
33	1.518	0.284	10.595	1.544	0.710	0.187
34	1.621	0.344	11.970	1.657	0.760	0.212
35	1.769	0.398	12.695	1.813	0.910	0.225
36	1.969	0.444	12.699	2.019	1.148	0.225
37	2.224	0.482	12.222	2.276	1.459	0.217
38	2.530	0.520	11.614	2.583	1.828	0.206
39	2.882	0.566	11.108	2.937	2.238	0.196
40	3.274	0.620	10.726	3.332	2.673	0.189
41	3.694	0.673	10.330	3.755	3.114	0.182
42	4.131	0.715	9.818	4.193	3.540	0.173
43	4.575	0.735	9.127	4.634	3.933	0.161
44	5.014	0.723	8.208	5.066	4.273	0.144
45	5.437	0.669	7.017	5.478	4.539	0.123

Table C.4 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition

Ship Speed (kts)	Net Drag Force (lbf)	Net Side Force (lbf)	Angle (Deg + clockwise from dead aft)	Magnitude	CR*1000	L/D Ratio
16	0.459	-0.021	-2.672	0.460	1.677	0.047
17	0.517	-0.020	-2.179	0.517	1.658	0.038
18	0.563	-0.025	-2.517	0.563	1.236	0.044
19	0.604	-0.033	-3.117	0.605	0.953	0.054
20	0.647	-0.040	-3.563	0.648	0.923	0.062
21	0.699	-0.043	-3.532	0.700	1.102	0.062
22	0.767	-0.038	-2.819	0.768	1.250	0.049
23	0.847	-0.024	-1.598	0.848	1.144	0.028
24	0.918	-0.005	-0.315	0.918	0.930	0.005
25	0.958	0.013	0.794	0.958	0.809	0.014
26	0.954	0.027	1.643	0.954	0.692	0.029
27	0.936	0.036	2.214	0.937	0.461	0.039
28	0.944	0.040	2.399	0.945	0.218	0.042
29	1.014	0.037	2.089	1.015	0.127	0.036
30	1.140	0.026	1.294	1.140	0.212	0.023
31	1.286	0.001	0.062	1.286	0.435	0.001
32	1.415	-0.040	-1.634	1.415	0.662	0.029
33	1.504	-0.095	-3.600	1.507	0.749	0.063
34	1.549	-0.141	-5.193	1.555	0.679	0.091
35	1.548	-0.157	-5.781	1.556	0.412	0.101
36	1.504	-0.124	-4.732	1.509	0.030	0.083
37	1.432	-0.044	-1.777	1.433	-0.265	0.031
38	1.354	0.078	3.278	1.356	-0.500	0.057
39	1.289	0.235	10.336	1.310	-0.726	0.182
40	1.250	0.415	18.366	1.318	-0.885	0.332
41	1.244	0.599	25.721	1.381	-0.984	0.482
42	1.275	0.769	31.082	1.489	-1.017	0.603
43	1.351	0.906	33.833	1.626	-1.007	0.670
44	1.476	0.991	33.861	1.778	-0.917	0.671
45	1.658	1.006	31.245	1.939	-0.708	0.607

Table C.5 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 1 degree inboard

Ship Speed	Net Drag Force	Net Side Force	Angle	Magnitude	CR*1000	L/D Ratio
(kts)	(lbf)	(lbf)	(Deg + clockwise from dead aft)	(lbf)		
16	0.458	-0.070	-8.738	0.463	1.317	0.154
17	0.496	-0.083	-9.509	0.503	1.259	0.168
18	0.547	-0.097	-10.055	0.555	1.223	0.177
19	0.605	-0.110	-10.320	0.615	1.203	0.182
20	0.667	-0.122	-10.333	0.678	1.188	0.182
21	0.729	-0.130	-10.121	0.741	1.166	0.179
22	0.789	-0.135	-9.705	0.800	1.125	0.171
23	0.842	-0.135	-9.088	0.852	1.053	0.160
24	0.887	-0.129	-8.304	0.896	0.949	0.146
25	0.924	-0.120	-7.412	0.932	0.815	0.130
26	0.953	-0.108	-6.461	0.959	0.657	0.113
27	0.980	-0.095	-5.561	0.985	0.495	0.097
28	1.018	-0.088	-4.961	1.022	0.374	0.087
29	1.082	-0.093	-4.910	1.086	0.342	0.086
30	1.181	-0.114	-5.517	1.186	0.424	0.097
31	1.296	-0.152	-6.683	1.305	0.557	0.117
32	1.405	-0.206	-8.326	1.420	0.660	0.146
33	1.487	-0.273	-10.393	1.511	0.662	0.183
34	1.533	-0.338	-12.422	1.570	0.560	0.220
35	1.542	-0.380	-13.852	1.588	0.375	0.247
36	1.511	-0.381	-14.137	1.558	0.131	0.252
37	1.454	-0.333	-12.909	1.492	-0.137	0.229
38	1.396	-0.243	-9.888	1.417	-0.387	0.174
39	1.363	-0.116	-4.885	1.368	-0.575	0.085
40	1.368	0.036	1.516	1.368	-0.681	0.026
41	1.408	0.196	7.925	1.422	-0.718	0.139
42	1.481	0.344	13.075	1.520	-0.699	0.232
43	1.581	0.461	16.239	1.647	-0.638	0.291
44	1.706	0.527	17.158	1.786	-0.550	0.309
45	1.852	0.523	15.782	1.924	-0.448	0.283

Table C.6 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 2.5 degrees inboard

Ship Speed	Net Drag Force	Net Side Force	Angle	Magnitude	CR*1000	L/D Ratio
(kts)	(lbf)	(lbf)	(Deg + clockwise from dead aft)	(lbf)		
16	0.439	-0.133	-16.820	0.458	1.139	0.302
17	0.492	-0.157	-17.712	0.516	1.171	0.319
18	0.546	-0.177	-17.982	0.574	1.173	0.325
19	0.596	-0.187	-17.403	0.624	1.120	0.313
20	0.646	-0.197	-16.936	0.675	1.048	0.305
21	0.702	-0.220	-17.385	0.736	1.000	0.313
22	0.761	-0.252	-18.288	0.802	0.967	0.330
23	0.818	-0.282	-19.026	0.866	0.929	0.345
24	0.868	-0.302	-19.174	0.919	0.861	0.348
25	0.907	-0.304	-18.500	0.957	0.749	0.335
26	0.941	-0.294	-17.375	0.986	0.611	0.313
27	0.976	-0.286	-16.324	1.017	0.478	0.293
28	1.020	-0.290	-15.845	1.061	0.379	0.284
29	1.080	-0.315	-16.261	1.125	0.338	0.292
30	1.152	-0.361	-17.371	1.208	0.345	0.313
31	1.233	-0.421	-18.867	1.303	0.374	0.342
32	1.316	-0.492	-20.520	1.405	0.405	0.374
33	1.395	-0.569	-22.176	1.506	0.414	0.408
34	1.456	-0.639	-23.691	1.590	0.371	0.439
35	1.485	-0.692	-24.977	1.638	0.253	0.466
36	1.475	-0.719	-26.010	1.641	0.062	0.488
37	1.428	-0.718	-26.683	1.598	-0.183	0.503
38	1.375	-0.681	-26.368	1.534	-0.425	0.496
39	1.353	-0.605	-24.102	1.482	-0.593	0.447
40	1.390	-0.497	-19.668	1.476	-0.641	0.357
41	1.464	-0.399	-15.260	1.517	-0.622	0.273
42	1.558	-0.313	-11.365	1.589	-0.572	0.201
43	1.666	-0.229	-7.841	1.682	-0.509	0.138
44	1.790	-0.184	-5.861	1.800	-0.431	0.103
45	1.936	-0.215	-6.346	1.948	-0.330	0.111

Table C.7 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 5 degrees inboard

Ship Speed	Net Drag Force	Net Side Force	Angle	Magnitude	CR*1000	L/D Ratio
(kts)	(lbf)	(lbf)	(Deg + clockwise from dead aft)	(lbf)		
16	0.449	-0.337	-36.897	0.562	1.368	0.751
17	0.544	-0.451	-39.644	0.707	1.374	0.829
18	0.614	-0.513	-39.841	0.800	1.378	0.834
19	0.668	-0.548	-39.347	0.864	1.376	0.820
20	0.712	-0.572	-38.801	0.914	1.365	0.804
21	0.752	-0.597	-38.465	0.960	1.342	0.794
22	0.791	-0.627	-38.429	1.009	1.297	0.793
23	0.832	-0.666	-38.691	1.066	1.223	0.801
24	0.876	-0.714	-39.196	1.130	1.112	0.815
25	0.923	-0.771	-39.871	1.203	0.958	0.835
26	0.974	-0.836	-40.651	1.284	0.782	0.859
27	1.027	-0.908	-41.485	1.370	0.609	0.884
28	1.080	-0.984	-42.345	1.461	0.465	0.911
29	1.132	-1.064	-43.217	1.553	0.372	0.940
30	1.181	-1.145	-44.101	1.645	0.318	0.969
31	1.226	-1.226	-45.003	1.734	0.284	1.000
32	1.264	-1.306	-45.931	1.817	0.247	1.033
33	1.295	-1.384	-46.892	1.895	0.191	1.068
34	1.319	-1.459	-47.885	1.966	0.106	1.106
35	1.335	-1.530	-48.903	2.030	-0.011	1.146
36	1.344	-1.598	-49.923	2.088	-0.166	1.189
37	1.351	-1.662	-50.906	2.142	-0.355	1.231
38	1.357	-1.723	-51.790	2.193	-0.534	1.270
39	1.368	-1.781	-52.489	2.246	-0.642	1.303
40	1.390	-1.838	-52.892	2.304	-0.641	1.322
41	1.433	-1.893	-52.868	2.374	-0.585	1.321
42	1.507	-1.948	-52.276	2.462	-0.501	1.293
43	1.623	-2.004	-50.987	2.579	-0.397	1.234
44	1.799	-2.063	-48.916	2.737	-0.278	1.147
45	2.050	-2.127	-46.056	2.953	-0.153	1.038

Table C.8 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 1 degree outboard

Ship Speed (kts)	Net Drag Force (lbf)	Net Side Force (lbf)	Angle (Deg + clockwise from dead aft)	Magnitude (lbf)	CR*1000	L/D Ratio
16	0.448	0.026	3.289	0.448	1.290	0.057
17	0.465	0.019	2.303	0.466	0.915	0.040
18	0.500	0.016	1.882	0.500	0.695	0.033
19	0.549	0.020	2.038	0.549	0.716	0.036
20	0.608	0.028	2.628	0.609	0.875	0.046
21	0.676	0.042	3.515	0.677	1.043	0.061
22	0.749	0.060	4.599	0.752	1.126	0.080
23	0.825	0.084	5.816	0.829	1.091	0.102
24	0.897	0.111	7.075	0.904	0.949	0.124
25	0.944	0.139	8.393	0.954	0.742	0.148
26	0.941	0.165	9.940	0.956	0.523	0.175
27	0.913	0.186	11.494	0.932	0.338	0.203
28	0.941	0.199	11.956	0.962	0.220	0.212
29	1.024	0.204	11.246	1.044	0.179	0.199
30	1.122	0.197	9.947	1.139	0.207	0.175
31	1.225	0.181	8.392	1.239	0.278	0.148
32	1.323	0.157	6.785	1.332	0.354	0.119
33	1.405	0.130	5.287	1.411	0.396	0.093
34	1.463	0.111	4.334	1.467	0.370	0.076
35	1.487	0.116	4.458	1.491	0.255	0.078
36	1.466	0.160	6.246	1.475	0.048	0.109
37	1.393	0.250	10.163	1.415	-0.233	0.179
38	1.284	0.380	16.499	1.339	-0.550	0.296
39	1.204	0.548	24.491	1.323	-0.847	0.456
40	1.170	0.744	32.447	1.387	-1.066	0.636
41	1.181	0.947	38.743	1.514	-1.155	0.802
42	1.232	1.137	42.713	1.677	-1.090	0.923
43	1.322	1.294	44.375	1.850	-0.902	0.978
44	1.448	1.395	43.928	2.011	-0.708	0.963
45	1.608	1.421	41.472	2.146	-0.750	0.884

Table C.9 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 2.5 degrees outboard

Ship Speed (kts)	Net Drag Force (lbf)	Net Side Force (lbf)	Angle (Deg + clockwise from dead aft)	Magnitude (lbf)	CR*1000	L/D Ratio
16	0.458	0.120	14.679	0.474	1.333	0.262
17	0.453	0.103	12.836	0.464	0.843	0.228
18	0.476	0.101	11.938	0.487	0.598	0.211
19	0.528	0.112	11.960	0.540	0.564	0.212
20	0.597	0.135	12.706	0.612	0.665	0.225
21	0.672	0.167	13.937	0.692	0.825	0.248
22	0.747	0.206	15.426	0.774	0.970	0.276
23	0.816	0.250	17.035	0.854	1.025	0.306
24	0.877	0.296	18.654	0.926	0.962	0.338
25	0.924	0.340	20.194	0.985	0.798	0.368
26	0.944	0.378	21.809	1.016	0.551	0.400
27	0.926	0.407	23.733	1.012	0.266	0.440
28	0.921	0.432	25.119	1.017	0.034	0.469
29	0.979	0.453	24.844	1.079	-0.049	0.463
30	1.089	0.473	23.484	1.188	0.071	0.434
31	1.219	0.486	21.735	1.313	0.287	0.399
32	1.337	0.485	19.930	1.422	0.461	0.363
33	1.413	0.466	18.234	1.488	0.474	0.329
34	1.443	0.449	17.277	1.511	0.334	0.311
35	1.431	0.465	18.002	1.504	0.107	0.325
36	1.381	0.543	21.453	1.484	-0.146	0.393
37	1.303	0.685	27.720	1.472	-0.401	0.525
38	1.221	0.873	35.552	1.501	-0.665	0.715
39	1.162	1.088	43.114	1.591	-0.946	0.936
40	1.146	1.312	48.865	1.742	-1.229	1.145
41	1.172	1.531	52.564	1.929	-1.467	1.306
42	1.232	1.729	54.542	2.123	-1.607	1.404
43	1.316	1.891	55.170	2.304	-1.600	1.437
44	1.417	2.002	54.710	2.453	-1.396	1.413
45	1.526	2.046	53.279	2.553	-0.943	1.341

Table C.10 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 5 degrees outboard

Ship Speed	Net Drag Force	Net Side Force	Angle	Magnitude	CR*1000	L/D Ratio
(kts)	(lbf)	(lbf)	(Deg + clockwise from dead aft)	(lbf)		
16	0.512	0.272	27.952	0.580	1.984	0.531
17	0.435	0.342	38.171	0.553	0.626	0.786
18	0.403	0.412	45.587	0.576	-0.065	1.021
19	0.410	0.478	49.412	0.630	-0.338	1.167
20	0.446	0.539	50.443	0.700	-0.363	1.211
21	0.504	0.595	49.758	0.780	-0.251	1.182
22	0.578	0.646	48.208	0.867	-0.078	1.119
23	0.661	0.693	46.367	0.958	0.108	1.049
24	0.748	0.738	44.591	1.051	0.276	0.986
25	0.836	0.782	43.092	1.144	0.407	0.936
26	0.918	0.827	41.988	1.236	0.492	0.900
27	0.994	0.874	41.342	1.323	0.527	0.880
28	1.059	0.926	41.187	1.407	0.514	0.875
29	1.112	0.985	41.536	1.485	0.454	0.886
30	1.151	1.051	42.392	1.559	0.354	0.913
31	1.177	1.127	43.744	1.629	0.221	0.957
32	1.189	1.213	45.569	1.699	0.061	1.020
33	1.189	1.312	47.824	1.771	-0.118	1.104
34	1.177	1.425	50.439	1.849	-0.308	1.210
35	1.157	1.553	53.317	1.936	-0.501	1.342
36	1.130	1.696	56.336	2.038	-0.689	1.501
37	1.101	1.857	59.349	2.159	-0.865	1.688
38	1.073	2.036	62.209	2.301	-1.021	1.897
39	1.052	2.233	64.773	2.469	-1.151	2.123
40	1.044	2.450	66.921	2.663	-1.249	2.347
41	1.054	2.684	68.557	2.883	-1.306	2.546
42	1.090	2.932	69.601	3.128	-1.319	2.689
43	1.160	3.180	69.963	3.385	-1.280	2.742
44	1.271	3.392	69.460	3.623	-1.186	2.669
45	1.433	3.469	67.549	3.753	-1.029	2.420

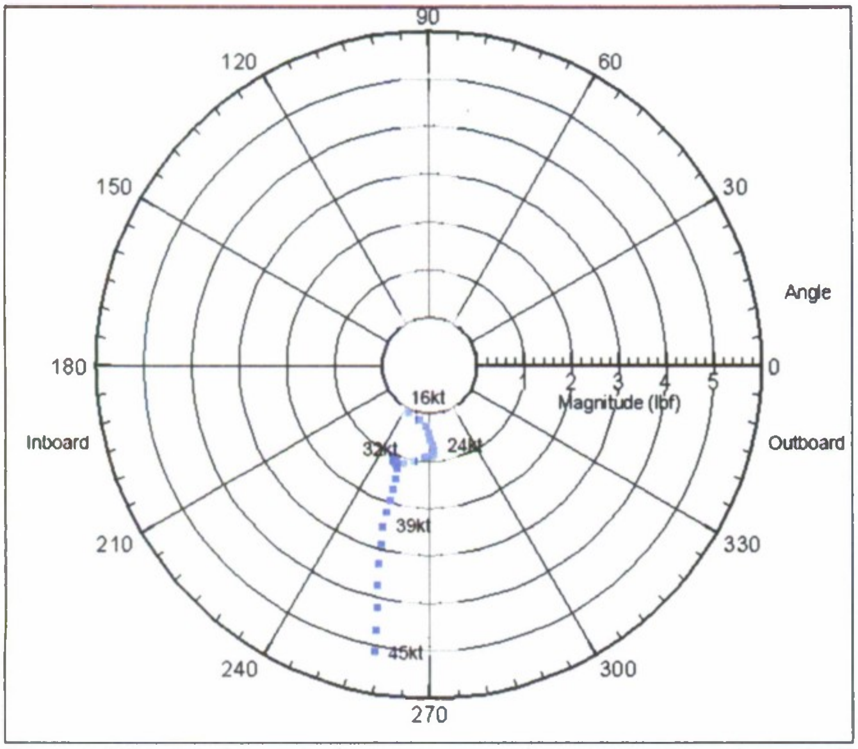


Figure C.1 – Model scale forces measured on the starboard side hull in the inboard forward trimaran condition

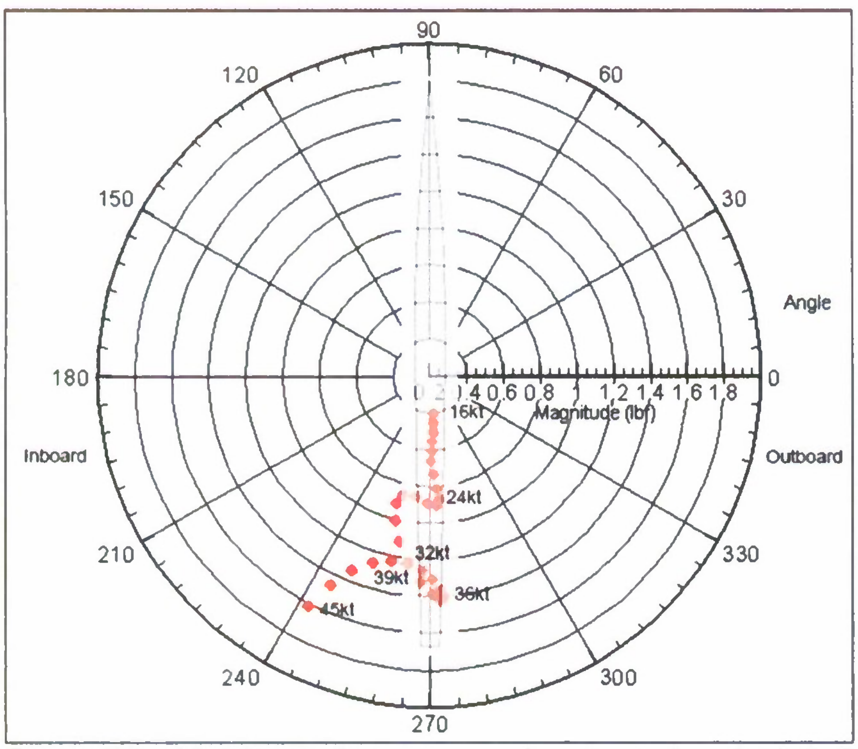


Figure C.2 – Model scale forces measured on the starboard side hull in the inboard aft trimaran condition

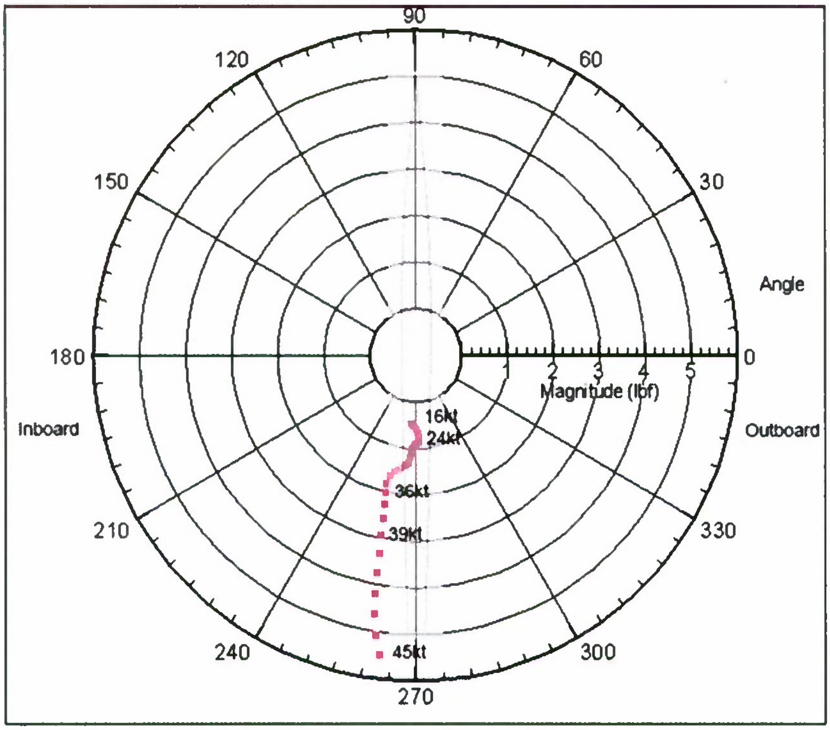


Figure C.3 – Model scale forces measured on the starboard side hull in the outboard forward trimaran condition

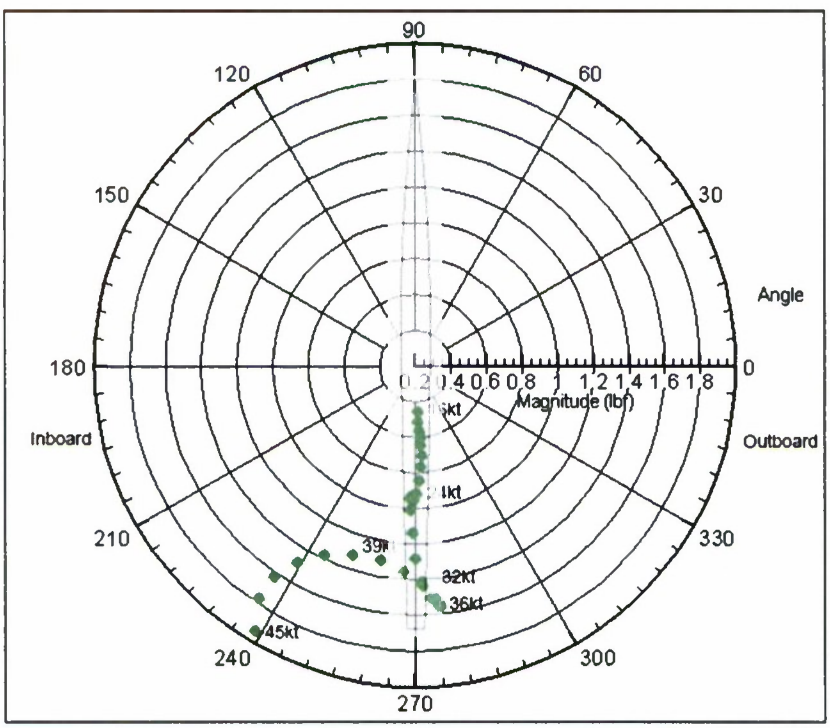


Figure C.4 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition

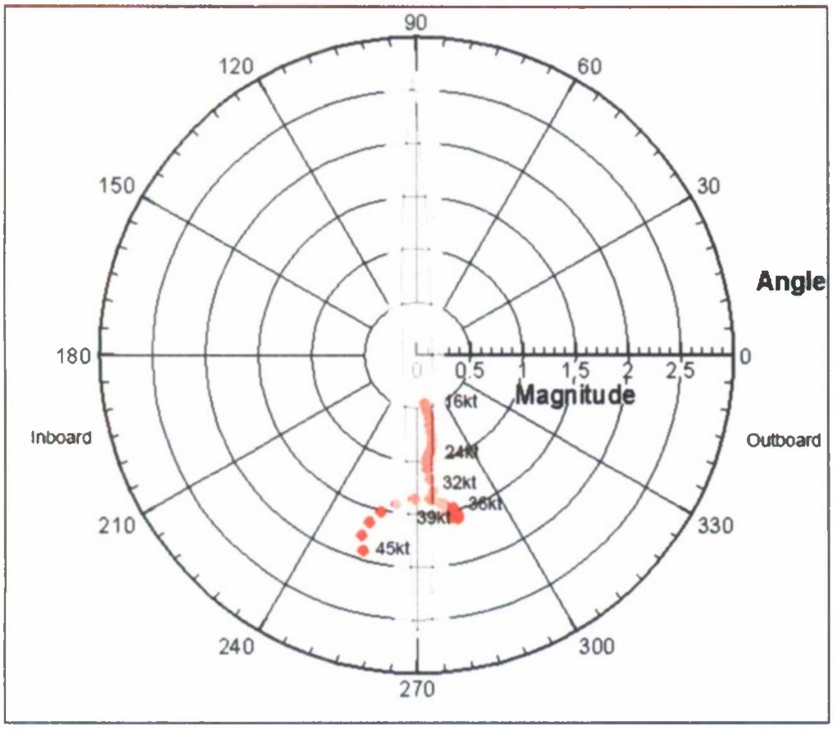


Figure C.5 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 1 degree inboard

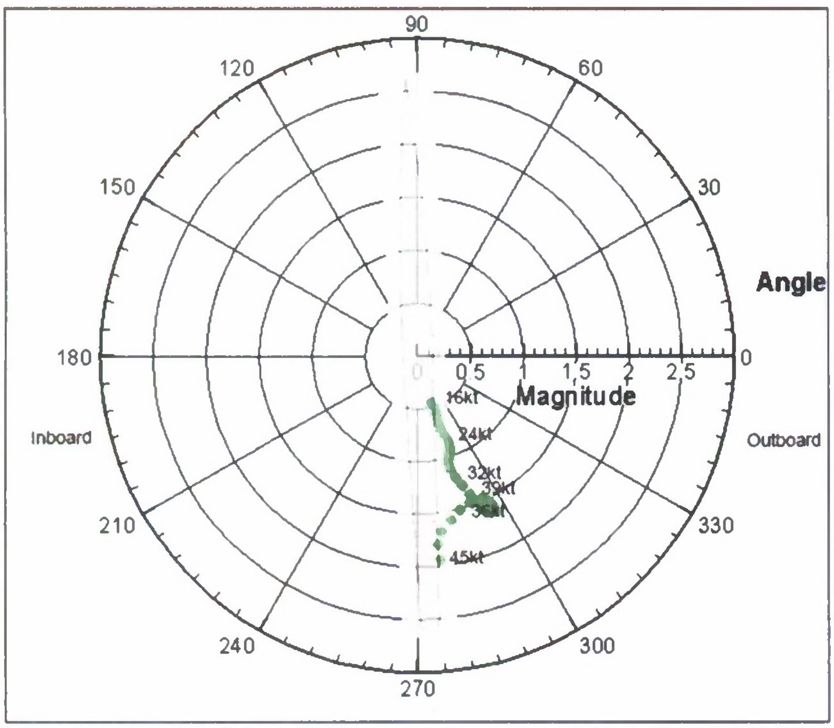


Figure C.6 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 2.5 degrees inboard

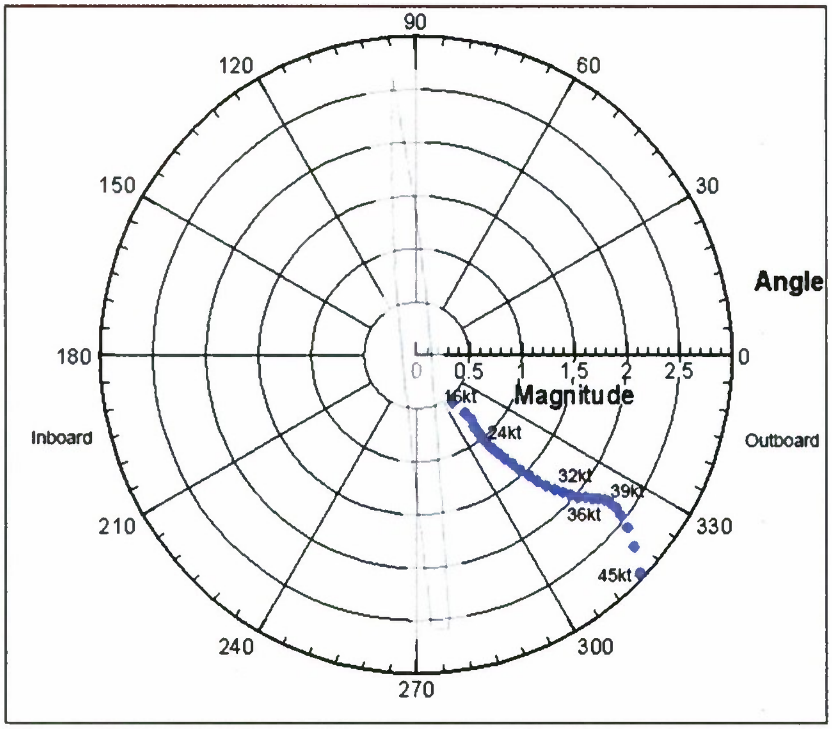


Figure C.7 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 5 degrees inboard

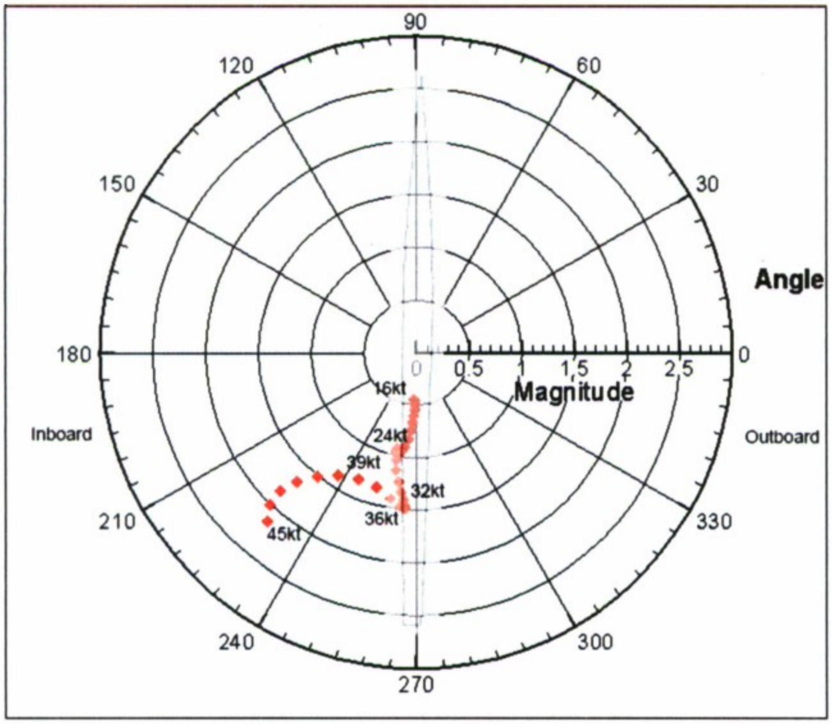


Figure C.8 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 1 degree outboard

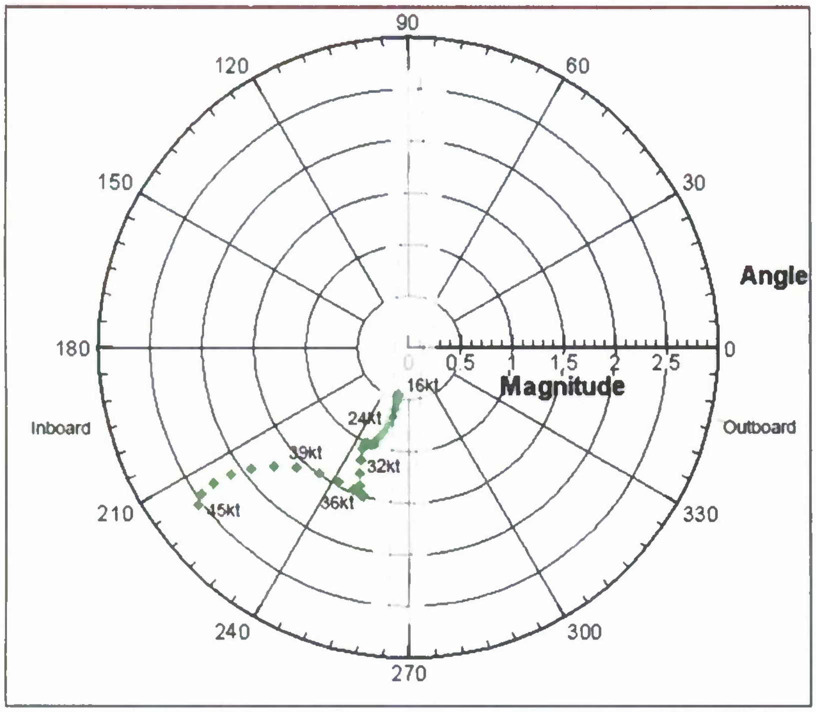


Figure C.9 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 2.5 degrees outboard

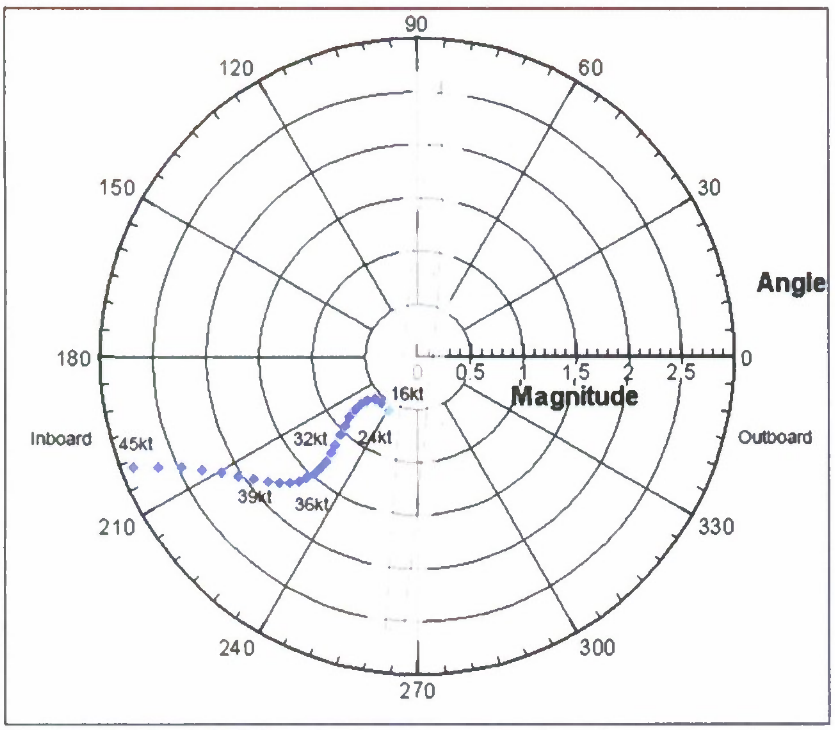


Figure C.10 – Model scale forces measured on the starboard side hull in the outboard aft trimaran condition with a toe angle of 5 degrees outboard

Table C.11– Effective power for both side hulls based on drag measured on the starboard side hull in the inboard forward trimaran condition

Experiment Name   Side Hulls Inbd Fwd from AMTI Gauge (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.2	ft^2	12.25	ft^2
Δ	4010.4	LT	81.33	lb/ft3
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	0.000010692	ft^2/s
CA			0.000	

Ship Speed (kts)	Effective Power (hp)	(kW)	Frictional Power (hp)	(kW)	Froude Number	V-L	1000CR
16	2625.1	1957.6	1522.6	1135.4	0.226	0.761	1.118
17	3160.8	2357.0	1812.6	1351.7	0.241	0.809	1.140
18	3656.9	2726.9	2136.5	1593.2	0.255	0.857	1.083
19	4104.1	3060.4	2496.0	1861.3	0.269	0.904	0.974
20	4525.1	3374.4	2892.9	2157.2	0.283	0.952	0.848
21	4975.1	3709.9	3328.9	2482.3	0.297	0.999	0.738
22	5551.8	4140.0	3805.7	2837.9	0.311	1.047	0.681
23	6401.0	4773.2	4325.1	3225.2	0.326	1.094	0.709
24	7552.4	5631.9	4888.7	3645.5	0.340	1.142	0.801
25	8792.7	6556.7	5498.3	4100.1	0.354	1.190	0.876
26	9759.1	7277.3	6155.5	4590.2	0.368	1.237	0.852
27	10156.7	7573.8	6862.1	5117.1	0.382	1.285	0.695
28	10141.0	7562.1	7619.6	5682.0	0.396	1.332	0.477
29	10073.6	7511.9	8429.9	6286.1	0.410	1.380	0.280
30	10373.9	7735.8	9294.4	6930.9	0.425	1.428	0.166
31	11059.3	8246.9	10215.0	7617.3	0.439	1.475	0.118
32	11965.1	8922.4	11193.2	8346.8	0.453	1.523	0.098
33	12890.5	9612.4	12230.7	9120.4	0.467	1.570	0.076
34	14042.4	10471.4	13329.1	9939.5	0.481	1.618	0.075
35	15955.2	11897.8	14490.1	10805.2	0.495	1.666	0.142
36	19314.0	14402.5	15715.2	11718.8	0.510	1.713	0.320
37	24487.7	18260.5	17006.2	12681.5	0.524	1.761	0.614
38	31430.2	23437.5	18364.6	13694.5	0.538	1.808	0.989
39	39982.9	29815.2	19792.1	14759.0	0.552	1.856	1.414
40	49982.6	37272.0	21290.3	15876.2	0.566	1.903	1.863
41	61351.6	45749.9	22860.7	17047.2	0.580	1.951	2.320
42	73968.3	55158.1	24505.0	18273.4	0.594	1.999	2.774
43	87646.8	65358.2	26224.7	19555.8	0.609	2.046	3.209
44	102128.9	76157.5	28021.6	20895.7	0.623	2.094	3.614
45	117075.9	87303.5	29897.1	22294.2	0.637	2.141	3.975

Table C.12 – Effective power for both side hulls based on drag measured on the starboard side hull in the inboard aft trimaran condition

Experiment Name Side Hulls Inbd Aft from AMTI Gauge (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.2	ft^2	12.25	ft^2
Δ	4010.4	LT	81.33	lb/ft3
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	0.000010692	ft^2/s
CA			0.000	

Ship Speed (kts)	Effective Power (hp)	(kW)	Frictional Power (hp)	(kW)	Froude Number	V-L	1000CR
16	2249.9	1677.8	1522.6	1135.4	0.226	0.761	0.738
17	2736.5	2040.6	1812.6	1351.7	0.241	0.809	0.781
18	3289.0	2452.6	2136.5	1593.2	0.255	0.857	0.821
19	3919.4	2922.7	2496.0	1861.3	0.269	0.904	0.862
20	4613.0	3439.9	2892.9	2157.2	0.283	0.952	0.893
21	5358.1	3995.5	3328.9	2482.3	0.297	0.999	0.910
22	6123.7	4566.5	3805.7	2837.9	0.311	1.047	0.904
23	6840.8	5101.2	4325.1	3225.2	0.326	1.094	0.859
24	7324.6	5462.0	4888.7	3645.5	0.340	1.142	0.732
25	7389.4	5510.3	5498.3	4100.1	0.354	1.190	0.503
26	7022.8	5236.9	6155.5	4590.2	0.368	1.237	0.205
27	6585.7	4911.0	6862.1	5117.1	0.382	1.285	-0.058
28	6605.8	4926.0	7619.6	5682.0	0.396	1.332	-0.192
29	7171.9	5348.1	8429.9	6286.1	0.410	1.380	-0.214
30	8284.1	6177.5	9294.4	6930.9	0.425	1.428	-0.155
31	9830.6	7330.7	10215.0	7617.3	0.439	1.475	-0.054
32	11593.0	8644.9	11193.2	8346.8	0.453	1.523	0.051
33	13249.6	9880.2	12230.7	9120.4	0.467	1.570	0.118
34	14443.7	10770.6	13329.1	9939.5	0.481	1.618	0.118
35	14805.5	11040.4	14490.1	10805.2	0.495	1.666	0.031
36	14257.2	10631.6	15715.2	11718.8	0.510	1.713	-0.130
37	12900.3	9619.8	17006.2	12681.5	0.524	1.761	-0.337
38	11010.3	8210.4	18364.6	13694.5	0.538	1.808	-0.557
39	9073.0	6765.7	19792.1	14759.0	0.552	1.856	-0.751
40	7255.3	5410.3	21290.3	15876.2	0.566	1.903	-0.911
41	5796.6	4322.5	22860.7	17047.2	0.580	1.951	-1.029
42	4931.8	3677.7	24505.0	18273.4	0.594	1.999	-1.098
43	4825.9	3598.7	26224.7	19555.8	0.609	2.046	-1.118
44	5376.1	4008.9	28021.6	20895.7	0.623	2.094	-1.104
45	6325.4	4716.9	29897.1	22294.2	0.637	2.141	-1.075

Table C.13 – Effective power for both side hulls based on drag measured on the starboard side hull in the outboard forward trimaran condition

Experiment Name: Side Hulls Outbd Fwd from AMTI Gauge (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.2	ft^2	12.25	ft^2
Δ	4010.4	LT	81.33	lb/ft3
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	1.07E-05	ft^2/s
CA			0.000	

Ship Speed (kts)	Effective Power (hp)	Effective Power (kW)	Frictional Power (hp)	Frictional Power (kW)	Froude Number	V-L	1000CR
16	3097.7	2310.0	1522.6	1135.4	0.226	0.761	1.598
17	3320.2	2475.9	1812.6	1351.7	0.241	0.809	1.275
18	3702.3	2760.8	2136.5	1593.2	0.255	0.857	1.115
19	4315.2	3217.9	2496.0	1861.3	0.269	0.904	1.102
20	5142.9	3835.1	2892.9	2157.2	0.283	0.952	1.168
21	6113.6	4558.9	3328.9	2482.3	0.297	0.999	1.249
22	7082.1	5281.1	3805.7	2837.9	0.311	1.047	1.278
23	7817.9	5829.8	4325.1	3225.2	0.326	1.094	1.193
24	8247.1	6149.9	4888.7	3645.5	0.340	1.142	1.009
25	8639.9	6442.8	5498.3	4100.1	0.354	1.190	0.835
26	9464.1	7057.4	6155.5	4590.2	0.368	1.237	0.782
27	11075.1	8258.7	6862.1	5117.1	0.382	1.285	0.889
28	13172.1	9822.4	7619.6	5682.0	0.396	1.332	1.051
29	15140.0	11289.9	8429.9	6286.1	0.410	1.380	1.143
30	16314.6	12165.8	9294.4	6930.9	0.425	1.428	1.080
31	16839.5	12557.2	10215.0	7617.3	0.439	1.475	0.924
32	17274.3	12881.5	11193.2	8346.8	0.453	1.523	0.771
33	18371.4	13699.6	12230.7	9120.4	0.467	1.570	0.710
34	20522.0	15303.3	13329.1	9939.5	0.481	1.618	0.760
35	23885.1	17811.1	14490.1	10805.2	0.495	1.666	0.910
36	28606.8	21332.1	15715.2	11718.8	0.510	1.713	1.148
37	34794.0	25945.9	17006.2	12681.5	0.524	1.761	1.459
38	42503.7	31695.0	18364.6	13694.5	0.538	1.808	1.828
39	51749.8	38589.8	19792.1	14759.0	0.552	1.856	2.238
40	62474.7	46587.4	21290.3	15876.2	0.566	1.903	2.673
41	74520.7	55570.1	22860.7	17047.2	0.580	1.951	3.114
42	87642.1	65354.7	24505.0	18273.4	0.594	1.999	3.540
43	101495.7	75685.3	26224.7	19555.8	0.609	2.046	3.933
44	115628.8	86224.4	28021.6	20895.7	0.623	2.094	4.273
45	129467.2	96543.7	29897.1	22294.2	0.637	2.141	4.539

Table C.14 – Effective power for both side hulls based on drag measured on the starboard side hull in the outboard aft trimaran condition

Experiment Name   Side Hulls Outbd Aft from AMTI Gauge (PE from CR Input)

	Ship		Model	
λ			47.53	
LWL	441.6	ft	9.29	ft
S	27666.2	ft^2	12.25	ft^2
Δ	4010.4	LT	81.33	lb/ft3
ρ	64.04235	lb/ft^3	62.2532	lb/ft^3
ν	1.28E-05	ft^2/s	0.000010692	ft^2/s
CA			0.000	

Ship Speed (kts)	Effective Power (hp)	(kW)	Frictional Power (hp)	(kW)	Froude Number	V-L	1000CR
16	3176.1	2368.4	1522.6	1135.4	0.226	0.761	1.677
17	3773.7	2814.1	1812.6	1351.7	0.241	0.809	1.658
18	3871.7	2887.2	2136.5	1593.2	0.255	0.857	1.236
19	4069.7	3034.8	2496.0	1861.3	0.269	0.904	0.953
20	4670.2	3482.6	2892.9	2157.2	0.283	0.952	0.923
21	5785.9	4314.5	3328.9	2482.3	0.297	0.999	1.102
22	7009.3	5226.8	3805.7	2837.9	0.311	1.047	1.250
23	7674.9	5723.1	4325.1	3225.2	0.326	1.094	1.144
24	7984.4	5954.0	4888.7	3645.5	0.340	1.142	0.930
25	8540.0	6368.2	5498.3	4100.1	0.354	1.190	0.809
26	9085.1	6774.8	6155.5	4590.2	0.368	1.237	0.692
27	9045.3	6745.1	6862.1	5117.1	0.382	1.285	0.461
28	8774.1	6542.8	7619.6	5682.0	0.396	1.332	0.218
29	9175.3	6842.0	8429.9	6286.1	0.410	1.380	0.127
30	10671.6	7957.8	9294.4	6930.9	0.425	1.428	0.212
31	13335.8	9944.5	10215.0	7617.3	0.439	1.475	0.435
32	16415.9	12241.4	11193.2	8346.8	0.453	1.523	0.662
33	18710.0	13952.0	12230.7	9120.4	0.467	1.570	0.749
34	19757.4	14733.1	13329.1	9939.5	0.481	1.618	0.679
35	18747.0	13979.6	14490.1	10805.2	0.495	1.666	0.412
36	16055.2	11972.4	15715.2	11718.8	0.510	1.713	0.030
37	13769.4	10267.9	17006.2	12681.5	0.524	1.761	-0.265
38	11757.0	8767.2	18364.6	13694.5	0.538	1.808	-0.500
39	9419.5	7024.1	19792.1	14759.0	0.552	1.856	-0.726
40	7654.2	5707.7	21290.3	15876.2	0.566	1.903	-0.885
41	6540.9	4877.5	22860.7	17047.2	0.580	1.951	-0.984
42	6374.7	4753.6	24505.0	18273.4	0.594	1.999	-1.017
43	6957.5	5188.2	26224.7	19555.8	0.609	2.046	-1.007
44	9227.1	6880.6	28021.6	20895.7	0.623	2.094	-0.917
45	14377.7	10721.4	29897.1	22294.2	0.637	2.141	-0.708

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